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HALIFAX, NOVA SCOTIA

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INTRODUCTION

F. J. SIMPSON

The Atlantic Regional Laboratory of the National Research Council of Canada celebrated its 25th Anniversary in October of 1977 with a series of events including lectures, symposia, open house to which the public was invited, a banquet, and a staff party.

It was on June 16th, 1952 that Dr E. W. R. Steacie, President of the National Research Council, officially opened the laboratory. In his address, Dr E. W. R. Steacie said:

> "By devoting itself to research along lines connected with the problems of the Maritime Provinces, it is our hope that we may make some contributions to the welfare of these provinces, and to the assistance of Maritime industry.... It seems to me that the ideal government laboratory is one which does applied research in an academic atmosphere.... The main function of such a laboratory should be to do the long-term general things which no single industrial firm can or will do for itself. In short, it is to have the academic approach, but applied to problems of specific interest."

This philosophy has guided the development of research programs at the Atlantic Regional Laboratory throughout its first 25 years.

Dr E. Gordon Young, a graduate of McGill and Cambridge Universities and professor of biochemistry at Dalhousie University, was the first Director. Under his leadership, the laboratory was organized into four sections for the study of biological, chemical, engineering and metallurgical sciences. Biological scientists studied some aspects of the nutrition of animals and humans, haemotology, the fermentation of apple juice, the autolysis of cod fillets, the control of fungal slime in pulp and paper mills, and the physiology of plankton and seaweeds. The chemists examined the chemical changes that occurred in potatoes during storage, the chemical composition of peat, the nature and deposition of pitch in pulp mills and the chemistry of the polysaccharides in seaweeds. A dryer was designed for the commercial drying of seaweed and built by the Engineering group, and the Metallurgical group commenced a series of studies on the kinetics of chemical reactions that occur during the processes of extracting iron from ores and the making of steel.

Dr A. C. Neish, a graduate of the Nova Scotia Agricultural College at Truro and Macdonald College (McGill University), succeeded Dr Young as Director in 1962. Plans for an addition were prepared, and a new wing completed in 1967 doubled the amount of laboratory space. Concomitant with this was an expansion of the research programs to include work on lichens, the production of antibiotics and toxins by microorganisms, the chemistry of natural products including hallucinogens and pesticides, and the physical chemistry of ice and water. The resources of the entire laboratory were marshalled in 1970 to assist in the clean up and investigations on problems resulting from the spill of bunker-C oil in Chedabucto Bay as a result of the wreck of the "Arrow". Some studies on specific aspects of the clean-up continued for several years after the major task was completed. In 1967, land for a seaweed culture station was acquired on the shores of the Atlantic Ocean and there, in some

war-surplus huts and a greenhouse, Dr A. C. Neish worked on Chondrus crispus (Irish moss) until he became seriously ill in 1972.

Dr F. J. Simpson, a graduate of the Universities of Alberta and Wisconsin, was appointed Director in 1973. Within the prevailing economic constraints the major research programs were further developed around a core of well equipped physical chemists who use such analytical techniques as electron microscopy, infra-red spectrometry, mass spectrometry, nuclear-magnetic-resonance spectrometry and X-ray diffraction spectrometry as their main experimental tools. The scientists responsible for these instruments carry out their own research programs and provide other members of the staff and collaborating scientists in other organizations with access to these highly specialized techniques. Though the research work on pesticides and hallucinogens was terminated, work on establishing reference materials, chemical standards, and improved analytical procedures for marine chemists, was begun. The research on marine algae was expanded, and knowledge obtained from 25 years of research is being applied to development of methods of cultivating these plants on a large scale for use in the food industry, or as sources of industrial chemicals, and as a means of providing experimental material grown under controlled conditions for biochemical and chemical studies. The study of toxins produced by fungi present in the soil and on pasture grasses, and the effect of such toxins on the fermentation in the rumen of sheep and cattle may provide an answer as to why these animals frequently do not fare well during late summer on Nova Scotian pastures. Knowledge gained from years of study on the constitution and structure of metallurgical slags and glasses and on the kinetics and thermodynamics of processes in the extraction of metals from ores is being applied to the removal of hydrogen from steel, the removal of sulfur from coal, coke and steel, and the extraction of lead and silver. Because of their expertise in the analysis of silicates, scientists at ARL participated in analyses of lunar fines brought back from the Moon by the Apollo flights.

From its beginnings, ARL has been involved with universities and industries in the Atlantic region; in fact, cooperative efforts between scientists within and without the laboratory are a way of life at ARL. Some of the staff have honorary appointments at Dalhousie and Acadia Universities and some university scientists and students from time to time are guest workers at ARL. Other members of the ARL staff are involved in research projects with the Sydney Steel Corporation, Brunswick Mining and Smelting, Marine Colloids Ltd., Genu Products Canada Ltd., and PEI Seaweeds Ltd.

On the occasion of its 25th Anniversary, the Atlantic Regional Laboratory honored those mainly responsible for guiding the laboratory's development. Among the first on the scene was Dr W. H. Cook, then Director of the Division of Applied Biology of the National Research Council in Ottawa. Dr Cook joined the National Research Council in 1930. After serving as a Director of a Division between 1941 and 1968, Dr Cook was appointed Executive Director and Assistant to the President for two years before retiring. He also was Director General of the Canadian Committee on the International Biological Program. Dr Cook played a major role in the development of the National Research Council, and the establishment and development of the Regional Laboratories. He was invited to be the principal speaker at the Anniversary Banquet held on October 13th and his address is reproduced here. Also honored at that

banquet were six members of staff who have been with the laboratory throughout its history, the Vice-President, Mr W. C. Cumming, and President W. Schnieder. The President presented the laboratory with a position for an annual Distinguished Visiting Scientist on the occasion of its 25th Anniversary.

The first Director of ARL, Dr E. Gordon Young was honored at a Memorial Symposium held on the afternoon of October 13th at Dalhousie University. The chairman was Dr W. Yaphe of McGill University and the speakers were Dr W. W. Hawkins (NRC), Dr G. H. N. Towers, of the University of British Columbia, and Dr R. G. S. Bidwell of Queen's University. The chairman and each speaker were former members of the Atlantic Regional Laboratory and, with the exception of Towers, had worked under Dr Young. The lectures were profusely illustrated with colored slides, but only the texts and data are reproduced here. The Atlantic Regional Laboratory, Dalhousie University and the Nova Scotian Institute of Science joined the A. C. Neish Memorial Trust in sponsoring the second A. C. Neish Memorial Lecture on October 12th. This lecture was given by Dr A. W. Galston of Yale University. Dr Galston, in speaking on Science and Social Concern, traced the history of the discovery of plant hormones and the development and application of herbicides with particular reference to their application in Vietnam, and possible consequences with respect to plant ecology and the effects of traces of dioxins on animal health. It is the latter part of his lecture that is published here. Readers interested in other accounts of Dr Galston's visits to Vietnam may consult the reports by D. Shapley and on dioxin by A. Hay. Dr Galston also profusely illustrated his lecture with color slides illustrating the effects of herbicides on plants and depicting the style of life in Vietnam.

REFERENCES

COOK, W. H. 1971. My 50 Years with NRC, 1924-1974: An Autobiography. Unpubl. ms., NRC Archives, Ottawa, Ont.

HAY, A. 1978. Vietnam's dioxin problem. Nature (London), 271: 597-98.

HOWELL, D. R. S., and Masson, C. R. 1974-1976. E. Gordon Young, 1919-1976. Proc. N. S. Inst. Sci. 27: 182-84.

JONES, J. K. N. 1974. Arthur Charles Neish. Bibl. Mem. of Fellows R. Soc. London 20: 295-315.

MACRAE, J. S. (Editor) 1977. ARL, the First Quarter Century. The Staff Association, Atlantic Regional Laboratory, National Research Council of Canada, Halifax, N. S.

MASSON, C. R. 1974-1976. A. C. Neish Memorial Lecture, introductory remarks. Proc. N. S. Inst. Sci. 27: 104-106.

SHAPLEY, D. 1975. Science in Vietnam: The postwar North seeks American assistance. Science, 189: 705-07.

SHAPLEY, D. 1977. Famous war general due to take over Vietnamese science. Science, 198: 173-74.

GENESIS OF NRC LABORATORIES

W. H. COOK

This pleasant gathering forms part of ARL's 25th anniversary celebrations. Such gatherings reflect a pride of accomplishment, and I would like to congratulate the staff for planning and executing such an event. As one who served only as a sort of midwife at the birth of the laboratory, it has been gratifying to witness growth and achievements of the offspring. Halifax must certainly provide a healthy environment for intellectual endeavor - the phenomenal growth of Dalhousie University in the last quarter century confirms this fact. On the personal side, this gathering has provided an opportinuty to meet old friends and associates and, on behalf of my wife and myself, may I thank you for your kind invitation.

But there was a catch in this. I was asked to say something about the histroy of ARL to an audience that had a full day and a full meal. While I accepted this challenge with enthusiasm, it soon became evident that the factual and detailed history of ARL had been written from several vantage points by those who made it. My personal concern with ARL was during its gestation period, viewed largely from a distance and now dimmed by time. I have, therefore, chosen to include something about the genesis of other NRC laboratories, for all had a different beginning, and are products of their parentage, environment, and time.

Science had some important ancestors going back to prehistoric times. We don't know when to celebrate the anniversary of the discovery of the wheel, but it did require creative imagination, and facilitated human progress. The experimental method must have been developed before early man could recover metals and chip his way out of the Stone Age. Then a much more abstract concept brought an even more creative advance. By devising symbols and arranging them in a consistent order, man gained a written language and mathematics. Now he could record his observations and experience for future generations.

By this time it was evident that there was an order in nature extending from the life cycles of living things to the orbiting of the planets. Agriculture and astronomy were about the earliest scientific disciplines. The reasons for this order were not evident, so man again used his imagination and developed mythologies to provide an explanation. Astronomy is one of the oldest sciences, but in Copernicus' day astrology was at least as important. A cynic, seeing the astrology columns in our daily papers, might say this has not changed in the past 500 years!

But a few believed that the order in nature could be explained, and undertook the acquisition of basic knowledge by experimentation to obtain facts. Progress was slow initially, for the experimental method requires both time and facilities. University staff had some time but few resources to pursue such a hobby. Gradually they acquired sufficient new basic knowledge to add Natural Philosophy to the curriculum. Meanwhile, government found that this basic knowledge could be developed for military purposes and civilian advancement. Industry found these developments to be profitable. As a result, both government and

industry began to support research wherever it could be done and eventually to establish their own research laboratories.

The events that precede the birth of a government laboratory reflect most of the stages involved in human reproduction. Conception takes place at a mating of the scientific and political communities. It starts with individuals, but the exchanges that occur in the barrooms and bedrooms of the nation are seldom recorded. The initial advances may be made by either party; but the only indication of sex is that the scientist is always for motherhood and the politician is often fickle. Conception is followed by a highly variable gestation period and the risk of a miscarriage. Birth is accompanied by labor pains and the screams of assorted midwives from every corner. Even when healthy at birth, the infant laboratory may be stunted by malnutrition or follow a wayward course into limbo. All of these events are reflected in one or more of the family of NRC laboratories.

In my opinion the formation of NRC in 1916 was promoted by politicians. Canadian scientists and industrialists were too few and too divided in opinion to have had much impact. Britain had started DSIR, and it was good political wisdom for Canada to take comparable action to enhance its scientific capabilities. The initial action was to appoint a Privy Council Committee for Scientific and Industrial Research, that in turn appointed an Advisory Committee that became known as NRC.

This Advisory Committee had only a limited mandate, to promote scientific research, and only limited funds to support such activity in existing institutions. Two facts were evident from the outset: first, there was little to promote or support a scientific capability which would have to be created; second, a central laboratory would be required to undertake major problems. The first need was undertaken by establishing graduate scholarships in science, and by supporting Associate Committees of professors who directed approved projects in their spare time without compensation. These were highly successful ventures but initially the scientific capability was so restricted that even the limited funds could not be fully used.

While it was evident that major projects could not be tackled without a central laboratory and full-time staff, such a plan would require a new Act to provide NRC with a broader mandate. It took five years for Council to develop an acceptable plan and create a receptive political climate. When it seemed certain that these requirements would be met, the first chairman of NRC, Dr A. B. Macallum, resigned. The required Bill did pass the Commons but was defeated in the Senate. The recorded reason was that expenditures on new things should not be made following a major war. The suggested reason is that the Senate was influenced by the mandarins of the bureaucracy who wanted NRC to be disbanded as a wartime agency, and thus remove competition for funds for Departmental science.

This miscarriage threatened the life of NRC. The Council did not resign - that would have been an admission of defeat - but continued to discharge its limited mandate. But building up a scientific capability that could not be used was a dead end, and Council had three chairmen in the next two years.

The NRC was saved from extinction by Dr H. M. Tory, a Nova Scotian from Guysborough County. During his career he established and presided over two Canadian universities in addition to NRC. He had a

firm conviction about the value of science, had the sympathy of scientists and educators, and the ability to convince the public and confront politicians. When he heard of the NRC debacle, he began a crusade, with speeches at universities, Canadian Clubs, and other formal and informal gatherings. In 1923 he was appointed a member of NRC and within a few months became its fifth chairman. In less than five years he obtained a new Act that gave NRC considerable freedom of action, a central laboratory and staff, with himself as its first fulltime President.

Then he was confronted by two new problems. The economic depression struck about the time the new building was started and slowed construction. Only the few staff that could be accommodated in temporary quarters had been employed before all appointments were cancelled. Then he had a personal problem. In an earlier day he had won a confrontation with a budding politician from Calgary who wanted the University of Alberta in his city. In 1930 the Honorable R. B. Bennett became Prime Minister and he thwarted Tory's plans at every opportunity. For example, the Prime Minister assigned the excess space in the new building to other agencies and used the funds, obtained by NRC for equipment, for the purchase of office furnishings for these agencies. It was to combat this influence that I was hastily transferred from temporary quarters at the University of Alberta early in 1932. My new responsibilities were to place orders for laboratory benches and services, including such major installations as a greenhouse and a battery of refrigerated rooms for the Division of Biology and Agriculture. It was the first time I had acted as midwife at the birth of a new laboratory, and it was a long and difficult period of labor. The combination of limited funds, red tape, and my inexperience extended these labor pains over the next three years.

In 1935 General A. G. L. McNaughton became President, the personal animosities disappeared, a modest growth in staff and facilities took place, but in 1939 the total NRC funds for scholarships, grants and the laboratories were still short of a million dollars annually.

The outbreak of war brought Dr C. J. Mackenzie, a graduate of Dalhousie University, to the Presidency of NRC. The staff and resources expanded about tenfold but this was expected to be for the duration only. However, Mackenzie inspired confidence at every level and under his leadership the Council's record of accomplishment justified the retention of its war-born growth. The NRC laboratories were now large enough to have a major impact on Canadian science. Decentralization was another major Mackenzie contribution; both regional laboratories were established during his regime.

The concept of a Prairie Regional Laboratory originated with the scientific community in response to public demand. The periodic unwieldy surpluses of wheat in North America had depressed prices. The United States had established four laboratories to find industrial uses for these surpluses, and the interested public were demanding similar action in Canada. In 1943 the NRC convened a conference of scientists from the prairie universities, government and industry, to determine the needs, the new projects to be undertaken, and to coordinate these with the responsibilities of existing laboratories. The outcome was a unanimous request for NRC to start a regional laboratory to undertake the new projects. This recommendation was approved in principle by NRC with construction to start in the immediate postwar period.

When Dr Mackenzie asked me to prepare a staff establishment and building for the new laboratory, there were adequate guidelines. The conference had proposed definite projects and war time shortages had required related studies that provided an experienced staff. These detailed plans were accepted by Council and approved by Treasury in February 1945, when the end of the war was in sight. The Council appointed its own architect, construction started in late 1945, the building was occupied in 1947, and officially opened in 1948. Drs A. C. Neish and F. J. Simpson were among the small band that transferred from Ottawa to give the new laboratory a flying start. The concept of PRL originated with the scientific community and gained both public and political support.

The initiative for establishing ARL originated on a more political level. Following the decision to establish PRL, there were speculations and rumors about NRC's starting laboratories in other regions but these gradually died down. Then following the Council meeting in May 1947, I was surprised to read in the Ottawa papers that NRC had announced it would establish a Maritime regional laboratory on a site provided by Dalhousie University. I had not heard of any new Maritime problem requiring attention, and there had not been a conference to formulate plans for the proposed laboratory or coordinate these with other federal laboratories in the region.

The conception of this laboratory took place in the politcal backrooms and remains unrecorded, but I gained a bit of the background from later conversations. When the clamor for more NRC regional laboratories was at its peak, the Honorable C. D. Howe had apparently conceived the notion of having all existing federal laboratories in a region consolidated in a building administered by NRC. Details of this plan are not available, but it would have led to NRC's becoming an administrative rather than a scientific institution.

About this time President A. E. Kerr was conducting a drive for funds for Dalhousie University, and he evidently felt it would be beneficial to have NRC announce that it would build a laboratory on the campus. He therefore offered NRC a site for a building - an over-generous offer considering the size of the Dalhousie campus at that time.

Naturally the scientific community was prepared to co-operate, and I suspect it was Dr C. J. Mackenzie who harmonized these diverse thoughts and desires into the concept of ARL. Shortly after the official announcement, he referred to my experience with PRL, and asked me to prepare a building and staff establishment for the new laboratory. I had doubts about this assignment; with one exception, I had no initmate knowledge of Maritime problems, and there had not been a conference to provide a directive on the scale of activities or indicate specific projects, as there had been for PRL. The only guide-line was that the laboratory was to serve biology, chemistry, and physics. Much later I learned that the original approval in principle contemplated a laboratory about half the size I eventually recommended and had approved.

Dr Mackenzie's persuasive power overcame my reluctance. He said the Public Works Department would be responsible for the construction of the building -all I had to do was to decide on the size and functional layout. As soon as a staff establishment had been approved, a director would be appointed and he could decide on the projects. It seemed easy but one has to have some idea of the size of building and services

required. A war-time emergency had acquainted me with one problem - seaweed utilization - and it was soon evident that this justified extension beyond our strictly laboratory effort. The requirements for such a project could be estimated and multiplied by three to take care of chemistry and physics when a director was appointed.

There were other problems. The initial plans contemplated the purchase of such services as steam and hot water from the University, as at PRL, but President Kerr insisted that the connections between the laboratory and Dalhousie University had to be kept on an intellectual level. By the end of 1947 the Public Works Department had completed the preliminary drawings and appointed an architect. To put it mildly, this architect evidently had no experience in the construction of laboratory buildings. He was in no hurry, seldom kept appointments, and never asked questions. The location of the building was decided while I was in the South Pacific; the new location required more expensive excavation and stone facing; costs now exceeded estimates and the size of the structure had to be reduced. On my return it was too late to remedy some of the more serious shortcomings arising from this change, such as some areas being below sewer level.

Construction started in late 1949, two years after the PWD had been provided with the initial plans. Dr E. Gordon Young was appointed Director in 1950, and the building completed shortly before the official opening in 1952. In 1951 I accompanied Dr Mackenzie to tidy up some details that would permit the staff to evacuate Dalhousie University premises.

Turning now to seaweed research. A project initiated in the Ottawa laboratories to meet a war emergency had provided my introduction to a Maritime problem. After Pearl Harbor, the usual sources of rubber and agar were cut off, and the government froze all available supplies for high priority purposes. The main user of agar was the food industry, but bacteriological and medical uses had priority. We were then asked to find a substitute for use in the food industry. The carrageenan extracted from Irish moss (Chondrus crispus) seemed an obvious choice for several reasons: (1) it set to a jelly in the presence of potassium salts; (2) it was used by the food industry for suspending chocolate in milk; (3) the seaweed was available along the Maritime coast; (4) this source had been developed by U.S. industry since European sources had been cut off.

The problem was not as simple as it seemed. From 1 to 2% of carrageenan was required to produce a satisfactory jelly for canned meat, and at this concentration most of the commercial extracts of that time, and our initial laboratory preparations, imparted an undesirable color or flavor. The suspension of chocolate in milk required only one-tenth this concentration, and the presence of chocolate masked both color and flavor. We were finally able to develop a suitable method of preparation and a formulation with potassium salts that was acceptable, although different extracts varied by a factor of two or more in their gelling and suspending power. This variability was only partly dependent on polymer size, as indicated by viscosity measurements.

In 1945 we resumed our work on carrageenan but with a different objective. There was a risk that this war-born export trade might be lost if cheaper suspending agents became available or if European sources of Irish moss were cheaper. It was soon found that carrageenan

reacted with the milk components to produce a much higher viscosity increment than less costly suspending agents. Yet Irish moss from European sources might be cheaper but, if the extracts from Canadian moss were of higher quality, requiring only half as much to suspend chocolate, they should be worth twice as much. A better understanding of the variable suspending power might provide a clue to quality for commercial purposes.

At that time the chemical structure of carrageenan was poorly understood and there was one suggestion in the literature that it might contain two components. If these extracts contained varying proportions of two or more components differing in suspending power, the variable performance could be explained and possibly reduced. Examination by a variety of chemical and physical methods showed that the extracts, in addition to the usual polydispersity, had properties indicative of two or more components. However, we were unable to distinguish these components analytically or separate them preparatively. Later, when we completed the installation of an analytical ultracentrifuge late one afternoon, a residual carrageenan solution was the most convenient test material. The quite unexpected separation of two components provided an analytical tool to monitor separation techniques.

Eventually Dr D. B. Smith separated the two components by differential precipitation from dilute solutions with potassium salts. During this study the two components had been designated α- and β-carrageenan, symbols that have a special meaning in polysaccharide chemistry. To avoid confusion, the symbols had to be changed for publication. When Smith asked me what we should call them, I suggested kappa for the potassium-sensitive fraction, and the next Greek letter lambda, for the other.

At this stage the project was transferrred to the new ARL, where subsequently the staff have inscribed the terms κ- and λ-carrageenan in the scientific literature by characterizing the components and relating them to the haploid and diploid phases of Irish moss.

But my visits to the Maritimes in 1948 showed that this seaweed problem went beyond the laboratory. There was concern about the extent of the beds, the rate of regeneration, drying methods, and the sanitary qualities of the product. The Nova Scotia Research Foundation, Dalhousie University, the two provincial governments, and industry, were all engaged on these problems. It appeared that the work of these diverse groups could be coordinated and enhanced by forming an NRC Associate Committee on Seaweed Research. Such action would have to be preceded by a conference to obtain the opinion of those concerned. With the assistance of Dr E. G. Young, such a conference was organized in Halifax in the autumn of 1948. Most of those attending came from Maritime institutions, but the representatives of U.S. industry, and Dr Neville Woodward, Director of the Scottish Seaweed Research Institute, did give it an international flavor. The meeting not only gave rise to an NRC committee, but it was also considered the first International Symposium on Seaweeds, that has continued to meet periodically ever since, the most recent being in August of this year.

When Dr E. W. R. Steacie became President of NRC in 1952, his first official act was to attend the formal opening of the ARL. At that time about a third of the staff had been employed, and they were all working on biologically-orientated problems, the majority on the seaweeds

project. On his return, he consulted me as to how the establishment had been arrived at, and I told him it had been obtained by formula. He expressed the view that the physical sciences should be represented in a regional laboratory, and said a project of this sort should be initiated to attract personnel. He imposed other requirements. The new project should be of regional interest and scientific importance, and I had no suggestions to offer. Later, Dr Steacie told me he had conceived of a suitable problem, high temperature metallurgy. DOSCO'S problems gave it regional interest and Sir Charles Goodeve had assured him of its scientific importance. With this decision he invited Dr C. R. Masson, who was already on staff, to head a team on high temperature metallurgy, and he was sent to BISRA for most of a year to learn the tricks of the trade. This action ensured that the physical sciences were adequately represented in the ARL.

I shall say little about the recent history of ARL. Dr Young brought the laboratory from infancy to maturity. Many new projects had been initiated and the building was completely filled when he retired in 1962. He remained active as a guest worker and completed his book, History of Canadian Biochemistry, before his death a year ago.

Dr A. C. Neish succeeded him and it was time for new growth. Neish had an addition built on the laboratory, introduced new projects including one in which he had a strong personal interest - the culture of marine plants. Neish spent his entire scientific career with NRC, first in Ottawa, then PRL, and finally in ARL. His achievements won him many honors, and the Council appointed him to the prestigious position of Distinguished Scientist, of which there are only two. The other is Dr Gerhard Herzberg. His untimely death was a sad loss to his family, his many friends, and to Canadian science. The mantle of leadership then fell to Dr F. J. Simpson, a long-time associate of Dr Neish at Ottawa and PRL, whom he had appointed as his Assistant Director at ARL.

Science has now reached an age of uncertainty. It started about 10 years ago when science policy became an international game and the Canadian Senate fielded a team. Their reports were critical rather than constructive. Perhaps they recognized that their overall policy pronouncements were a bit too vague for establishing scientific priorities, so they recommended new bureaucrasies to control and direct science. Rumor has it that they may even name a team to win the next Nobel Prize.

Then came the energy crisis that fanned the flames of inflation, and effectively reduced the budget for science. It also produced a pragmatic science policy, as laboratories everywhere increased their studies on wind power, solar energy, and the fusion reactor.

Meanwhile, society began to affect science policy. Initially they had accepted such scientific advances as antibiotics, DDT, and nuclear energy, with a sort of "Gee Whiz" acclaim. Alerted by some segments of the scientific community and by what they saw, the public began to question the long-term effects of some of these developments. First, DDT was banned because of its long-term effects on the environment. Then, the safety of nuclear power plants was questioned, and their construction delayed. In fact, extensive ecological studies were demanded before any large-scale developments were undertaken. Finally, the citizens of Cambridge, Mass. obtained a temporary ban on recombitant

DNA experiments in their district even before they had been undertaken. Scientific opinion may differ on the wisdom of some of these decisions, but there can be little doubt that the public have entered the science policy forum. They are likely to demand more rather than less research in applied fields that are related to health and the environment.

It is easier to forecast the changes that are likely to affect science policy than to predict scientific advances. Major scientific discoveries that change the whole course of science are unpredictable. In the last 25 years, science found the key to the genetic code, Sputnik opened the Space Age, and the old applied field of plant breeding produced the Green revolution. None of these major scientific advances could have been predicted when ARL was opened. The breakthroughs of the next 25 years cannot be predicted, but it is safe to say that enormous sums will be spent in studies on recombitant DNA, plant improvement, and the fusion reactor. The Green Revolution is close to one of ARL's interests. Nova Scotian bays are highly productive in plant material, and Neish's vision of a marine aquaculture may yet become a reality. If the animal species that reside in these bays could be encouraged to grow twice as fast, we might have another breakthrough that would produce a Protein Revolution.

In the international league of scientific research, a single laboratory cannot play in all the games. The games ARL has played during its first 25 years have brought the individual players a distinguished reputation and started the laboratory along the pathway toward excellence. May the standards you have established be continued through future anniversaries.

E. GORDON YOUNG MEMORIAL SYMPOSIUM

E. G. YOUNG AND THE ARL

W. W. HAWKINS

When I was asked to pay some tribute to Dr Young in this symposium I was pleased and honored; pleased because of our long friendship and honored because of my high regard and respect for him. I met him in 1939, and during the next 37 years it was my privilege to spend 12 of them with him, first as a graduate student at Dalhousie University and later as a research officer in the Atlantic Regional Laboratory; and in between and afterwards we kept in touch as friends.

E. Gordon Young had the faculty to stimulate and encourage the development of scientific thought in a student if the potentiality was there or if the ability had shown itself. His method was socratic, so the learning process was active. An objective approach with the use of this method is an ideal instrument for the purpose, and those of us who were exposed to it profited from it to the limit of our application and ability.

When man seeks to attain true scientific thought there are two innate obstacles to be dealt with: he is by nature a mystic and his emotions tend to be a great governing factor in his life. The extent to which he can control these two aspects of his being determines in large part the degree and quality of scientific thought of which he is capable. Learning to think objectively in a systematic and orderly way is one of the most difficult tasks that the human mind can set itself, but that is what is required of the scientist regardless of his discipline. The philosophy of science is founded upon objectivity. Whether or not complete objectivity has ever been obtained I do not know, but in my opinion it is a theoretical state. I do not think that man is capable of the necessary degree of ascetic mental discipline. Those scientists who attain an objective quality of thought well beyond the average, therefore, are scientists of an upper class; and E. Gordon Young was one of them.

It is natural that scientists in that class bring the philosophy of science into their personal philosophies, as did Dr Young. As a result, his approach to any concept or problem was predominantly objective and his thinking was analytical.

This quality of thought made it possible for him to cope successfully with research in different fields of his interest and to make his name and work known and respected in fields as far apart as human nutrition and the chemistry of marine algae. The same quality of thought, and his wide ranging knowledge, also made it possible for him to cope successfully with problems of a practical nature that require solution by the scientific method, and his contributions to this aspect of science were notable.

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*Chairman: W. Yaphe

Here, then, was a man who in the first half of this century became known internationally as a versatile scientist of high repute who had earned the esteem of his peers; and he lived and worked in Halifax from 1924 until the time of his death in 1976. On March 30th of that year an editorial in the Halifax Mail-Star eulogized him as follows:

> "The death of Dr E. Gordon Young is a reminder that we often are little aware of the distinguished stature of some of the individuals who dwell in our midst. It is the rare good fortune of this part of the country that such a man as Dr. Young made it the scene of his life's work, a work which reflects unmeasured credit upon Nova Scotia as well as upon this nation. As a teacher and research scientist, Dr. Young enjoyed international recognition."

The expression of this tribute is elaborate, but its essential content is true, as those who can judge know.

In 1947 it was announced that the National Research Council of Canada would establish a laboratory in Halifax on the campus of Dalhousie University. In it, research would be done in various fields of science, with particular attention to the interests and problems of the Atlantic provinces. His catholicity of interests, his scientific acumen, and his established reputation indicated Dr Young as a director to be sought; and he became the laboratory's first director in 1950. Details of structure and organization were worked out over the next two years and the laboratory was opened in 1952.

The scientific staff of that laboratory had the advantage and worked under the aegis of Dr Young's scientific outlook for 10 years. Work that produced results beneficial to industry and industrial development was done, but any scientist of Dr Young's calibre understands the fundamentally important relationship that exists between research in applied science and academic research. Consequently, fundamental research had its proper place in the laboratory.

The truly scientific approach to the enlargement of knowledge is disciplined and orderly. It is reasoning from what is known by progressive and ordered thinking to build a valid hypothesis and to select or create a trustworthy method for testing it. This has been called 'curiosity oriented research' by people who do not understand the philosophy of science or the scientific method, or indeed, who may not know that they exist. Curiosity is an element in the process but it is so rigorously controlled that its role is not prominent.

This was an important element in the direction of the work in the Atlantic Regional Laboratory during Dr Young's time as director. It is an element that is fundamental to the scientific process, and because it was properly regarded in the beginning, it was important in the development of the laboratory. Every director individually influences the quality and direction of the work in a laboratory. The importance of fundamental research to both the enrichment of human culture and the successful application of scientific knowledge for the material benefit of humanity characterized Dr Young's influence.

GREEN PLANTS THAT AFFECT HUMAN SKIN

G. H. N. TOWERS

Allergic contact dermatitis in North America usually is associated with members of the Anacardiaceae such as Rhus radicans (poison ivy), R. diversilobum (Eastern oakleaf poison ivy) and R. vernix (poison sumac). The sensitizing compounds are alkylated dihydroxy phenols, and they also occur in Japanese lacquer (R. vernicifera), mango (Mangifera indica), cashew nut shell oil (Anacardium occidentale), and Indian marking nut (Semecarpus sp.). Goldstein (1968) has given an interesting account of cross sensitivity to members of the Anacardiaceae.

The subject of contact allergy from plants has been reviewed recently by Mitchell (1975).

Allergic contact dermatitis, also known as delayed hypersensitivity or Type IV cell-mediated hypersensitivity (Roitt 1971), is produced by contact of the skin with low-molecular weight chemicals which sensitize blood lymphocytes. In a sensitized individual, the appearance of dermatitis, on re-exposure to the chemical, is delayed in onset by one to two days. The clinical manifestations are erythematous maculopapular rashes or papulovesicular eruptions on exposed areas of the body. Sensitization to a specific chemical is determined usually by a patch test.

Our collaborative studies at the University of British Columbia* originated with cases of allergic contact dermatitis evoked by species of Frullania, a genus of epiphytic liverworts, in forest workers in British Columbia. Over the years there had been cases reported in France and the Pacific Northwest of North America (Bleumink et al 1976; LeCoulant & Lopes 1956, 1960, 1966; Mitchell et al 1969, 1971; Storrs et al 1976). A simultaneous chemical investigation, by Ourisson's group in France, of the allergens led to the identification of the major sensitizer (Knoche et al 1969; Mitchell et al 1970; Perold et al 1972). This turned out to be a sesquiterpene lactone which was named frullanolide (Fig 1). It was found to be accompanied by other closely related sesquiterpene lactones such as costunolide and arbusculin-β which were later on also shown to be allergenic (Asakawa et al 1976; Green et al 1972; Perold et al 1972). Sesquiterpene lactones are low molecular weight, colorless, bitter, lipophilic constituents of plants, and more than 500 have been isolated and identified from many species of plants, chiefly from the family, Compositae (Devon & Scott 1972; Yoshioka et al 1973). Many of them have been shown to be biologically active eg, anti-tumor, cytotoxic or antibiotic (Rodriguez et al 1976b). Their cytotoxicity is often associated with the presence in the molecule of an α-methylene-ϒ-lactone (Kupchan et al 1971; Lee et al 1973), or an unsaturated α,β-ketonic moiety (Lee et al 1971; 1973).

So far the major sources of the 200 to 300 known sesquiterpene lactones are species of Compositae (Devon & Scott 1972; Yoshioka et al 1973) and, in the light of the results with Frullania, dermatitis resulting

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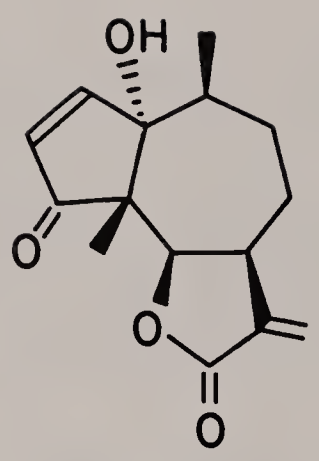
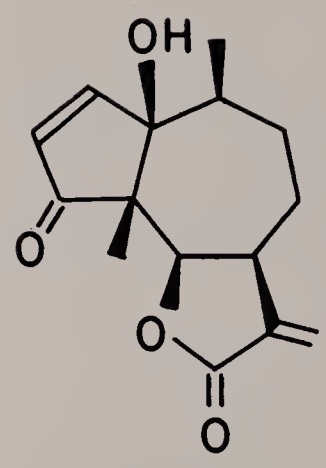
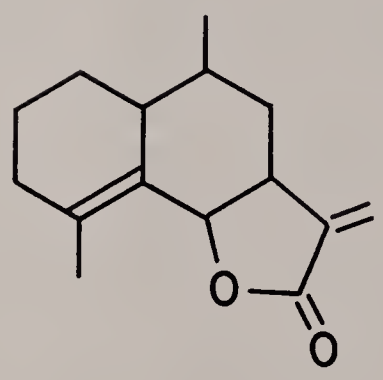


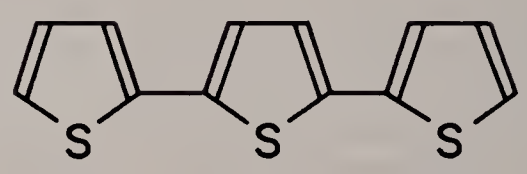
Parthenin



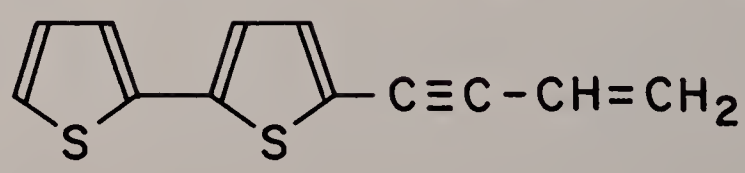
Hymenin



Frullanolide



α-Terthienyl



5-(3-Buten-1-ynyl)-2,2'-bithienyl

Fig 1. Structures of Parthenin, Hymenin, Frullanolide, α-terthienyl, and 5-(3-buten-1-ynyl)-2,2'-bithienyl.

from Compositae required a study. One of the 50 or more forest workers in British Columbia who had allergic contact dermatitis from Frullania also was discovered to be contact-sensitive to Chrysanthemum x morifolium (Mitchell et al 1970). Dermatitis caused by certain composites, eg, chrysanthemum, ragweed and tansy, has been known for many years (Greenhouse & Sulzberger 1933; Mitchell et al 1971; Nightingale 1931). Chrysanthemum x morifolium is the commonest reported cause of dermatitis from horticultural composites (Mitchell et al 1970, 1971). In West Germany, for instance, it is one of the most common causes of occupational contact dermatitis among gardeners and florists (Hausen & Schulz 1975, 1976) and one of the identified allergens was shown to be arteglasin-A, a sesquiterpene lactone of the guaianolide type (Hausen & Schulz 1975). About 60 species of Compositae, including well-known genera such as Ambrosia, Artemisia, Aster, Cosmos, Dahlia, Helianthus, Hieracium, Matricaria, Rudbeckia, Solidago, Tagetes and Xanthium, also have been reported to cause allergic contact dermatitis (Mitchell 1970). Sesquiterpene lactones, are distributed among all these groups with the exception of Tagetes. In an extensive study by our group, it was shown that a prerequisite for activity is a lactone moiety with an exocyclic -methylene function (Mitchell et al 1970). Reduction of the methylene to a methyl function results in loss of activity (Mitchell et al 1970). The allergenic properties of the sesquiterpene lactones, in other words, are correlated with their cytotoxic activities as shown by the work of others (Kupchan et al 1971).

Cross-sensitivity patterns to patch tests with crude plant extracts vary in sensitized individuals, and in general, highly sensitized individuals are found to show a wider spectrum of cross-sensitivity than weakly sensitized ones (Mitchell et al 1970; Hjorth & Roed-Peterson 1976).

Cross-sensitivity to specific plants is nothing more than a reflection of cross-sensitivity to specific sesquiterpene lactones, but the reasons for these differences between individuals are not obvious. Very few studies have been made of this interesting and complex phenomenon.

. Pyrethrum, also known as Dalmatian or Persian insect powder, consists of dried flower heads of Chrysanthemum cinerarifolium and C. coccineum. It is an effective insecticide and is used in scabiecidal and anti-mosquito preparations. It may cause allergic eczematous contact dermatitis (Anon. 1936; Lord & Johnson 1947; McCord 1962; McCord et al 1921; Martin & Hester 1941; Mitchell et al 1972; Sequeira 1936; Sulzberger & Weinberg 1930; Sweitzer 1936). In a patient with allergic contact dermatitis from pyrethrum, pyrethrosin, a sesquiterpene lactone which does not have insecticidal properties, was shown to be the principal allergen of pyrethrum derived from species of Chrysanthemum (Mitchell et al 1972).

'Australian bush dermatitis' is a chronic dermatitis of exposed areas occurring in men living in the Australian bush (Burry et al 1973). Although the dermatitis appears to be evoked by Compositae, as evidenced by positive patch tests to ragweed (Ambrosia) and other species of Compositae, the causative species is not always known. Cases of dermatitis caused by the Compositae, Arctotheca, Cassinea, Inula, and Artemisia are often referred to as a bush dermatitis in Australia.

In 1974, at the University of British Columbia, we had reached a stage in our dermatological and phytochemical investigations of weed dermatitis where we could pinpoint, confidently, the chemical source of

delayed hypersensitivity to Compositae as the sesquiterpene lactones contained in these plants. Dr Arvind Lonkar, a dermatologist from Poona, India, drew our attention to the high and increasing incidence of allergic contact dermatitis in that city from a new weed, Parthenium hysterophorus. This member of the Compositae is native to the Caribbean Islands, Central America, the southern United States and parts of Argentina, Brazil and Bolivia. It is an aggressive weed of disturbed sites and, within the last 100 yr, has found its way to Africa, Australia and to Asia. It has spread to a serious extent in India where is poses a serious agriculture problem as well as a medical hazard (Towers et al, in press).

Parthenium hysterophorus was first noticed in Poona, as an adventive in 1956 and increasing numbers of cases of dermatitis were traced to exposure to it. The dermatitis affected primarily the exposed skin surfaces, ie, surfaces not usually covered by clothing, of agricultural laborers but an increasing number of city dwellers became affected as the plant spread into urban regions (Lonkar et al 1974).

Contact allergy to Parthenium develops from repeated contacts with plants or possibly its disseminated parts and, after sensitization, itching eruptions occur on exposed parts of the body particularly the upper eyelids, sides of the neck, parts of the face, V-of the neck, fronts of elbows and backs of knees (Lonkar et al 1974). The skin shows vesiculation with exudation and pruritus is intense. As the dermatitis progresses lichenification, impetiginization, fissuring of the skin, and various pigmentary changes follow.

Allergic contact dermatitis from Parthenium had been known in rural workers in the southern United States for many years but, with urbanization and mechanization of farming practices, it has declined in incidence according to an experienced Texas dermatologist (J. B. Howell, in litt 1976).

In India, clinically and patch test established cases of Parthenium dermatitis have so far been reported from Poona (Lonkar et al 1974), Bangalore (Subba Rao et al 1976) and Delhi (J. S. Pasricha & D. N. Shivpuri in litt). Suspected cases of the dermatitis from Parthenium have also been reported anecdotally from other places, particularly in the states of Maharashtra and Karnataka where the weed is widespread. Initially, typical patients were adult males engaged in outdoor work, particularly farmers. In recent years, white-collar workers, bankers, doctors, policemen etc, were found to develop the allergy (Subba Rao et al 1976). A predilection of the dermatitis for adult males has been observed in America and India and is so far unexplained. Children before puberty are spared (Lonkar et al 1974), and no cases of Parthenium dermatitis were encountered in either women or children in the course of clinical studies in Bangalore (P. V. Subba Rao in litt).

The major sesquiterpene lactone in most populations of P. hysterophorus is the pseudoguaianolide, parthenin (Fig 1). Some plant populations from southern Texas and those from southern Bolivia and central Argentina contain the diastereomer, hymenin, (Fig 1) as the major lactone (Rodriguez 1975). Of 10 Indian patients sensitized to Parthenium and to parthenin none reacted to hymenin (Subba Rao et al unpubl.) indicating that it is not only the α-methylene lactone moiety that is important but also the configuration about the bridge carbon bearing a hydroxyl group. This would suggest that the double bond in the cyclopentenone ring may participate in the allergenic reaction(s). Helenalin

and tenulin, sesquiterpene lactones which bear cyclopentenone moieties, undergo a Michael-type addition reaction with the sulfhydryl groups of reduced glutathione and L-cysteine (Lee et al 1977). In the case of helenalin the α-methylene-ϒ-lactone system also acts as an alkylating center. We have found that parthenin forms as least two adducts with cysteine under relatively mild conditions (Picman et al, unpubl.). In one of these adducts it is the α-methylene function which is involved and, in the other, both the α-methylene as well as the double bond of the cyclopentenone ring. With sesquiterpene lactones which do not contain cyclopentenone rings, or other reactive centers, eg alantolactone, it is the α-methylene group of the lactone ring which reacts with sulfhydryl groups and is presumably involved in the allergic reaction. Obviously a great deal of study of the interaction of these compounds with membrane proteins of skin cells is needed.

Parthenin is located in the trichomes (plant hairs) of the leaves and stems (Rodriguez et al 1976a). These are easily broken off, particularly when the plants are dry and brittle and, obviously this is one way for aerial dissemination of the sensitizer. In some ways Parthenium dermatitis resembles American ragweed (Ambrosia) dermatitis in having an airborne pattern of distribution. In the case of ragweed the allergenic determinant is in the oleoresin of the pollen (Hjorth et al 1976). Small amounts of parthenin are obtained in chloroform extracts of pollen of Parthenium hysterophorus (Mangala & Subba Rao, unpubl.) and, according to Ranade (1976), the pollen is responsible for the eczematoid dermatitis. As Parthenium pollen is sticky however, forming clumps in the flower heads, it may not be wind borne easily and this is one explanation for the relative unimportance of Parthenium pollen in hay fever or allergic rhinitis (Kahn & Grothaus 1936).

The weed has spread to nearly all the states of India and in cities such as Poona, Hubli and Banglalore, occupying vacant lots, ditches, roadsides, etc. According to a survey of the State Agriculture Department (Towers et al, in press), it occupies nearly one-third of the 122 km^2 of the city area of Bangalore. People in India come in direct contact with the plant in various ways: (a) working in fields, (b) using vacant lots as toilets, (c) using the dried plant as fuel, (d) clearing lots or gardens, or (e) uprooting it manually. There are no epidemics of eczematous dermatitis in Havana (Cuba), Kingston (Jamaica), Port-of-Spain (Trinidad), or many southern United States and Mexican towns where the weed is prolific and conspicuous (personal observations). This must be a reflection of the habits of the people; certainly it does not seem to be genetic because in a country such as Trinidad, where Parthenium is abundant and 40 to 50% of the population is of East Indian origin, there is a very low incidence of the allergy.

Parthenium hysterophorus not only has invaded food and fodder crop fields in India but even forest nurseries. In areas particularly heavily infested, buffaloes and goats may graze on the weed giving rise to the problem of 'bitter milk'. The weed has been shown to be quite toxic to buffaloes and cattle when fed at 5% level in fodder. Autopsies reveal necrosis and lesions of the liver and gastro-intestinal tract (Narasimham et al, unpubl.).

Public awareness of the problem has increased in India and a start has been made in eradication programs in the more badly affected parts of the country.

It should be borne in mind that compounds other than sesquiterpene lactones may be involved in some cases of allergic contact dermatitis. For instance pyrethrin II, an ester of chrysanthemumic acid, is a known sensitizer from Chrysanthemum spp (Burry et al 1973). Similarly, Tagetes minuta (Mexican marigold), a common weed in south eastern Africa, has a vesicant primary irritant effect on intact skin and can cause severe and prolonged contact dermatitis (Verhagen & Nyaga 1974). So far sesquiterpene lactones have not been found in the genus or even in other members of the tribe, Tageteae (Rodriguez 1975).

Parthenium dermatitis bears a marked resemblance to photodermatitis (A. Lonkar in litt) which is caused by exposure to sunlight. It is well known that allergic contact dermatitis caused by Compositae is hard to distinguish from phytophotodermatitis (Curwen & Jilson 1960). For example, ragweed (Ambrosia) dermatitis has been misdiagnosed as a photo-dermatitis (Hjorth 1976). Is there any relation between allergic contact dermatitis and photodermatitis evoked by Compositae? We believe that there may well be in some instances and that more careful studies are needed. This leads to a discussion of photoactive chemicals in the Compositae.

There exists a number of types of compounds in plants which damage human skin in the presence of light, the best known of these being the linear furanocoumarins of the Apiaceae, Rutaceae, Papilionaceae and Moraceae (Pathak et al 1974). In sunlight or artificial sources of long wave ultra-violet light (360-370 nm) these compounds cause cell damage and current hypothesis involves covalent cross-linking between double stranded DNA and the furanocoumarin in photochemical reactions (Musajo et al 1974).

Furanocoumarins or psoralens are not only phototoxic to human skin but also to bacteria and fungi (Daniels 1965; Fowlks et al 1958). A chance discovery by Daniels (1965), a dermatologist, that the achenes of the garden marigold (Tagete) contain a chemical or chemicals phototoxic to the yeast, Candida albicans, led us to a phytochemical investigation of Tagetes for the active substance or substances. Two of the phototoxic compounds isolated from Tagetes patula were identified (Chan et al 1975) as the thiophene derivatives, α-terthienyl and 5-(3-buten-1-ynyl)-2,2'-bithienyl (Fig 1), compounds which had been shown previously to be phototoxic to the nematode, Pratylenchus penetrans (Gommers & Geerligs 1973).

Our study was extended to 80 other species of Compositae (Camm et al 1975), and more recently to nearly 300 North, Central and South American species (Towers et al, 1977). Leaves, stems, roots and achenes of each species were assayed separately using Candida albicans as test organism. There was excellent correlation between occurrences of certain polyacetylenes and their thiophene derivatives and phototoxic activity. The activity, usually restricted to stem, root or achene, was sometimes even restricted to the pappus of the achene as in Tagetes. Activity was correlated with the occurrence of compounds such as the tridecapentaynene [$CH_3 - (C \equiv C)_5 - CH = CH_2$], or esters of matricarionol [$CH_3 - CH = CH - (C \equiv C)_2 - CH = CH - CH_2OCOR$]. These compounds themselves as well as a number of other polyacetylenes and thiophene compounds were shown to be active. Carbonyl compounds conjugated with a double bond and further conjugated with triple bonds are phototoxic. Where this conjugation is lacking the compounds are

inactive. It is possible that the mode of action of the polyacetylenes is similar to that of the furanocoumarins, ie, a light-mediated cross-linking of double-stranded DNA, requiring two reactive sites in a given polyacetylene molecule. However, this remains to be studied.

We have found recently that α-terthienyl can evoke photodermatitis in human skin (Chan et al, 1977). Thus, burning pain and erythema developed within 20 min of long wave UV-irradiation of α-terthienyl skin sites in contrast to 8-methoxypsoralen-evoked photodermatitis which developed at about 4 h. α-Terthienyl and related thiophenes occur in many Compositae particularly in the Tribes Helenieae, Heliantheae and Tageteae. In Tagetes the highest concentrations are in the roots but it is also in the flower heads (Glushka et al, unpubl).

Tagetes minuta, as mentioned previously, is an adventive weed in East Africa and, apart from its other undesirable properties, causes severe irritation and edema of small wounds such as scratches (Verhagen & Nyaga 1974). Walking through a field of marigolds on a sunny afternoon could, therefore, be a hazard. I found that the exposure of an area of the forearm, which had been treated with 1% solution of α-terthienyl in petrolatum, resulted in severe erythema within a few minutes in the tropical sun and to hyperpigmentation which persisted after 6 mo.

So far polyacetylenes such as $\emptyset - (C \equiv C)_3 - CH_3$ or $CH_3 (C \equiv C) - CH = CH_2$, which we have established as being phototoxic to Candida and to certain pathogenic bacteria, have not been tested on human skin. It is more than likely that they have an effect and this could be important, particularly if these compounds are carried in pollen. Many Compositae contain polyacetylenes (Bohlmann et al 1973) as well as sesquiterpene lactones, and thus they may be capable of a dual 'attack' on exposed skin. The possibility of photodermatitis from Compositae is worth investigating, especially in those cases where eczematoid dermatitis bears a close resemblance to photo-dermatitis and where the offending species is known to contain reactive sesquiterpene lactones as well as photoactive polyacetylenes.

REFERENCES

ANONYMOUS, 1936. Pyrethrum dermatitis. Br. Med. J. i, 1936: 1262.

ASAKAWA, Y., MULLER, J. C., OURISSON, G., FOUSSEREAU, J., and DUCOMBS, G. 1976. Nouvelles lactones sesquiterpeniques de Frullania (Hepaticae). Bull. Soc. Chim. Fr. 1456-66.

BLEUMINK, E., MITCHELL, J. C., GEISSMAN, T. A., and TOWERS, G. H. N. 1976. Contact hypersensitivity to sesquiterpene lactones in Chrysanthemum dermatitis. Contact Dermatitis, 2: 81-88.

BOHLMANN, F., BURKHARDT, T., and ZDERO, C. 1973. Naturally Occurring Acetylenes. Academic Press, London.

BURRY, J. R., KUCHEL, R., REID, J. G., and KIRK, J. 1973. Australian Bush Dermatitis: Compositae dermatitis in South Africa. Med. J. Aust. 1: 111-116.

CAMM, E. L., TOWERS, G. H. N., and MITCHELL, J. C. 1975. UV-mediated antibiotic activity of some Compositae species. Phytochemistry, 14: 2007-11.

CHAN, G. F. Q., TOWERS, G. H. N., and MITCHELL, J. C. 1975. Ultraviolet-mediated antibiotic activity of thiophene compounds of Tagetes. Phytochemistry, 14: 2295-96.

CHAN, G. F. Q., PRIHODA, M., TOWERS, G. H. N., and MITCHELL, J. C. 1977. Photodermatitis evoked by α-terthienyl. Contact Dermatitis, 3: 215-16.

CURWEN, W. L. and JILSON, O. F. 1960. Light hypersensitivity; a simplified office procedure for diagnosis of contact photodermatitis. J. Invest. Dermatol. 34: 207-12.

DANIELS, F. 1965. A simple microbiological method for demonstrating phototoxic compounds. J. Invest. Dermatol. 44: 259-63.

DEVON, T. K. and SCOTT, A. I. 1972. Handbook of Naturally Occurring Compounds. Vol II. Terpenes. Academic Press, New York.

FOWLKS, W. L., GRIFFITH, D. G., and OGINSKY, E. L. 1958. Photosensitization of bacteria by furocoumarins and related compounds. Nature (London), 81: 571-72.

GLUSHKA, J., TOWERS, G. H. N., CHAN, G. F. Q., and MITCHELL, J. C. Unpublished results.

GOLDSTEIN, N. 1968. The ubiquitous urushiols - contact dermatitis from Mango, poison ivy and other "poison" plants. Cutis, 4: 679-85.

GOMMERS, F. J. and GEERLIGS, J. W. G. 1973. Lethal effect of near ultraviolet light on Pratylenchus penetrans from roots of Tagetes. Nematologica, 19: 389-93.

GREEN, A. E., MULLER, J. C. and OURISSON, G. 1972. A new approach to-methylene-ϒ-butyrolactones. Synthesis of (-)-frullanolide. Tetrahedron Lett. 2489-92.

GREENHOUSE, C. A., and SULZBERGER, M. A. 1933. Common weed tansy (Tanacetum vulgare) as a cause of eczematous dermatitis. J. Allergy, 4: 523-26.

HAUSEN, B. M. and SCHULZ, K. H. 1975. A first allergenic sesquiterpene lactone from Chrysanthemum indicum L: Arteglasin-A. Naturwissenschaften, 62: 585-86.

HAUSEN, B. M. and SCHULZ, K. H. 1976. Chrysanthemum allergy III. Identification of the allergens. Arch. Dermatol. Res. 255: 111-21.

HJORTH, N., ROED-PETERSON, J., and THOMSEN, K. 1976. Airborne contact dermatitis from Compositae oleoresins simulating photodermatitis. Br. J. Dermatol. 95: 613-39.

HJORTH, N. and ROED-PETERSON, J. 1976. Compositae sensitivity among patients with contact dermatitis. Contact Dermatitis, 2: 271-81.

KAHN, I. S. and GROTHAUS, E. M. 1936. Parthenium hysterophorus: [antigenic properties, respiratory and cutaneous. Tex. State J. Med. 32: 284-88.

KNOCHE, H., OURISSON, G., PEROLD, G. W., FOUSSEREAU, J., and MALEVILLE, J. 1969. Allergenic component of a liverwort: [a sesquiterpene lactone. Science, 166: 139-40.

KUPCHAN, S. M., EAKIN, M. A., and THOMAS, A. M. 1971. Tumor Inhibitors. [69. Structure-cytotoxicity relationships among the sesquiterpene lactones. J. Med. Chem. 14: 1147-52.

LECOULANT, M. P. and LOPES, G. 1956. A propos des dermites des bois. J. Med. Bordeaux 3: 245-49.

LECOULANT, M. P. and LOPES, G. 1960. Role pathogene des muscinees hepatiques dans les indistries du bois. Soc. Med. Hyg. Trav. 21: 374-76.

LECOULANT, M. P. and LOPES, G. 1966. L'allergie au Frullania: son role dans la "dermite du bois de chene". Bull. Soc. Fr. Dermatol. Syphiligr. 73: 440-43.

LEE, K-H., HALL, I. H., MAR, E-C., STARNES, C. O., and EL GREBALY, S. A. 1977. Sesquiterpene antitumour agents: Inhibitors of cellular metabolism. Science, 196: 533-36.

LEE, K. H., HUANG, E. H., PIANTADOSI, C., PAGANO, J. S., and GEISSMAN, T. A. 1971. Cytotoxicity of sesquiterpene lactones. Cancer Res. 31: 1649-54.

LEE, K. H., MECK, R., and PIANTADOSI, C. 1973. Antitumor agents. 4. Cytotoxicity and in vivo activity of helenalin esters and related derivatives. J. Med. Chem. 16: 299-301.

LONKAR, A., MITCHELL, J. C., and CALNAN, C. D. 1974. Contact dermatitis from Parthenium hysterophorus. Trans. St. John's Hosp. Dermatol. Soc. 60: 43-53.

LORD, K. A. and JOHNSON, C. G. 1947. Production of dermatitis by Pyrethrum and attempts to produce non-irritant extract. Br. J. Dermatol. 59: 367-75.

MCCORD, C. P. 1962. The occupational toxicity of cultivated flowers. Ind. Med. Surg. 31: 365-8.

MCCORD, C. P., KILKER, C. H., and MINSTER, D. K. 1921. Pyrethrum dermatitis; a record of the occurrence of occupational dermatoses among workers in the Pyrethrum industry. J. Am. Med. Assoc. 77: 448-9.

MANGALA, A. and SUBBA RAO, P. V. Unpublished results.

MARTIN, J. T. and HESTER, K. H. C. 1941. Dermatitis caused by insecticidal Pyrethrum flowers. Br. J. Dermatol, 53: 127-42.

MITCHELL, J. C. 1970. Allergic contact dermatitis from Compositae. Trans. St. John's Hosp. Dermatol. Soc. 55: 174-83.

MITCHELL, J. C. 1975. Contact allergy from plants. In: Recent Advances in Phytochemistry, Vol. 9 (ed. V. C. Runeckles), pp. 11-38. Plenum Press, N. Y.

MITCHELL, J. C., DUPUIS, G., and TOWERS, G. H. N. 1972. Allergic contact dermatitis from pyrethrum (Chrysanthemum spp.). The role of pyrethrosin, a sesquiterpene lactone, and of pyrethrin II. Br. J. Dermatol. 86: 568-73.

MITCHELL, J. C., FRITIG, B., SINGH, B., and TOWERS, G. H. N. 1970. Allergic contact dermatitis from Frullania and Compositae. The role of sesquiterpene lactones. J. Invest. Dermatol. 54: 233-39.

MITCHELL, J. C., GEISSMAN, T. A., DUPUIS, G., and TOWERS, G. H. N. 1971. Allergic contact dermatitis caused by Artemisia and Chrysanthemum species. J. Invest. Dermatol. 56: 98-101.

MITCHELL, J. C., ROYAL, A. K., DUPUIS, G., and TOWERS, G. H. N. 1971. Allergic contact dermatitis from ragweeds (Ambrosia species). Arch. Dermatol. 104: 73-76.

MITCHELL, J. C., SCHOFIELD, W. B. SINGH, B., and TOWERS, G. H. N. 1969. Allergy to Frullania: allergic contact dermatitis occurring in forest workers caused by exposure to Frullania nisquallensis. Arch. Dermatol. 100: 46-9.

MUSAJO, L., RODIGHIERO, G., CAPORALE, G., DALL'ACQUA, F., MARCIANI, S., BORDIN, F., BACICHETTI, F., and BEVILACQUA, R. 1974. Photoreactions between skin-photosensitizing furocoumarins and nucleic acids. In: Sunlight and Man. (ed. T. B. Fitzpatrick), pp. 369-88. Univ. Tokyo Press, Tokyo.

NARASIMHAN, T. R., ANANTH, M., BABU, M. R., MANGALA, A., and SUBBA RAO, P. V. Unpublished results.

NIGHTINGALE, G. S. 1931. Chrysanthemum dermatitis. Lancet, 16: 1132-34.

PATHAK, M. A., KRAMER, D. M., and FITZPATRICK, T. B. 1974. Photobiology and photochemistry of furocoumarins (Psoralens). In: Sunlight and Man, (ed. T. B. Fritzpatrick), pp. 335-68: Univ. of Tokyo Press, Tokyo.

PEROLD, G. W., MULLER, J. C., and OURISSON, G. 1972. Structure d'une lactone allergisante: le frullanolide-I. Tetrahedron, 28: 5797-5803.

PICMAN, A., TOWERS, G. H. N., RODRIGUEZ, E., JAMIESON, P., and PIERS, E. Unpublished results.

RANADE, S. 1976. Proc. of the seminar, "Parthenium-a positive danger", p. 15. BICRO and Univ. Agri. Sci., Bangalore, India.

RODRIGUEZ, E. 1975. The Chemistry and Distribution of Sesquiterpene Lactones and Flavonoids in Parthenium (Compositae): Systematic and Ecological Implications. Ph.D. Thesis. Univ. Texas, Austin.

RODRIGUEZ, E., DILLON, M., MABRY, T., MITCHELL, J. C., and TOWERS, G. H. N. 1976a. Dermatologically active sesquiterpene lactones in trichomes of Parthenium hysterophorus L. (Compositae). Experientia, 32: 236-38.

RODRIGUEZ, E., TOWERS, G. H. N., and MITCHELL, J. C. 1976b. Biological activities of sesquiterpene lactones - a review. Phytochemistry 15: 1573-80.

ROITT, I. 1971. Essential Immunology. Blackwell Sci. Publ., Oxford.

SEQUEIRA, J. H. 1936. Pyrethrum dermatitis. Br. J. Dermatol. 48: 473-76.

STORRS, F. J., MITCHELL, J. C., and RASMUSSEN, M. D. 1976. Contact hypersensitivity to liverwort and the Compositae family of plants. Cutis, 18: 681-86.

SUBBA RAO, P. V., MANGALA, A., SUBBA RAO, B. S., and PRAKASH, K. M. 1976. Proc. of the seminar, "Parthenium-a positive danger". p. 17. BICRO and Univ. Agric. Sci., Bangalore, India.

SUBBA RAO, P. V., RODRIGUEZ, E., and TOWERS, G. H. N. Unpublished results.

SULZBERGER, M. B. and WEINBERG, C. B. 1930. Dermatitis due to insect powder. J. Am. Med. Assoc. 95: 111-12.

SWEITZER, S. E. 1936. Scabies: Further observations on its treatment with Pyrethrum ointment. Lancet, 56: 467-68.

TOWERS, G. H. N., MITCHELL, J. C., RODRIGUEZ, E., SUBBA RAO, P. V., and BENNETT, F. D. Biology and chemistry of Parthenium hysterophorus L., a problem weed in India. Biochem. Rev. (in press).

TOWERS, G. H. N., WAT, C. K., GRAHAM, E., CHAN, G. F. Q., BANDONI, R. J., MITCHELL, J. C., and LAM, J. 1977 Ultraviolet-mediated antibiotic activity of species of Compositae caused by polyacetylenic compounds. Lloydia. 40: 487-98

VERHAGEN, A. R. and NYAGA, J. M. 1974. Contact dermatitis from Tagetes minuta. Arch. Dermatol. 110: 441-44.

YOSHIOKA, H., MABRY, J. T., and TIMMERMANN, B. N. 1973. Sesquiterpene Lactones. Univ. Tokyo Press, Tokyo.

THE CARBON DIOXIDE MACHINE, OR PLANTS ON THE MAKE

R. G. S. BIDWELL

Plants cover the world. They may be edible and intensely cultivated, or natural ground cover which is less useful but may be valuable as a natural resource or for cooking, heating, and industrial use, or just beautiful to look at; and sometimes they are serious pests. Usually plant growth is quite lush. However, there are many problem areas where plants have to face real problems in order to survive, such as salt pans in Australia or the rugged and inhospitable terrain north of the Great Wall in China. In fact, it is suprising that plants could grow in these unpleasant places at all. Once, in early geological times, plant growth was more lush, much more so than now, although we depend as much on today's plants for food as on yesterday's for coal and oil.

Why is plant growth not so lush as formerly? What are the problems that plants face growing in difficult or inhospitable situations? How are these problems solved? Plants are carbon dioxide machines. Carbon dioxide is the major nutrient for plants, and it is in short supply. Once there was a great deal of carbon dioxide in the atmosphere, but the plants of early days made profligate use of their raw materials, and now its concentration in the air is only 0.03%. For plants, the expression 'thin air' has special meaning! Plants also face a second problem: oxygen is a by-product of plant growth, and it is poisonous to plants. Finally (we will not consider minerals, although fertilizers represent an increasingly important problem in the world food supply) there is the problem of water that faces many plants. Land that is considered fit for agricultural use in Australia would be classified as a national disaster in North America! Plants nevertheless manage to grow in these areas in Australia. Let us look at some of the tricks plants have for dealing with this situation.

Water and carbon dioxide present a compound problem. Carbon dioxide, because of its low concentration, diffuses into the leaves down a very shallow gradient, while water diffuses out of the leaves down a very steep gradient (Fig 1). This problem can be somewhat alleviated 38 by the deposition of an impervious cuticle on the epidermis of the plants. Unfortunately, although it is impervious to water it is also impervious to CO_2. This problem can be solved by having small holes, called stomata, in the surface of the epidermis. CO_2 readily 'squeezes up' as it passes through these holes, so that the cuticle and epidermis offer very little barrier to the passage of CO_2 into the leaf. Water vapor, being saturated inside the leaf, cannot squeeze up very much, and consequently the epidermis strongly hinders its diffusion outwards. This arrangement works satisfactorily for many plants. However, when a drought occurs, the plants must close their stomata in order to avoid water loss. Then, even though the sun is shining (and the sun is the source of all energy for plant growth) no photosynthesis can take place.

There are thus three basic problems: water, carbon dioxide concentration, and oxygen. I shall examine different solutions that have

evolved in the plant kingdom, and a recent suggestion (from work done in collaboration with staff of the Atlantic Regional Laboratory while I was a guest there last year) on how seaweeds cope with these problems.

First I shall present the basic mechanisms of photosynthesis in broad outline. CO_2 enters a leaf through the stomata, and diffuses through the rather open mesophyll cells to the main photosynthetic tissue, which is the palisade layer near the top of the leaf. Sugars there formed must then diffuse to the leaf veins for translocation to other parts of the plant. The characteristic large air spaces require CO_2 to diffuse over long distances inside the leaf. Once the CO_2 has diffused to the photosynthetic cells, it moves (perhaps as bicarbonate - HCO^{3-}) into the chloroplast, where it encounters the photosynthetic carboxylase. In the majority of plants this is ribulose bisphosphate carboxylase (RuBPc'ase) which works as shown in Figure 2. The product of this carboxylase, two molecules of phosphoglyceric acid (PGA), are reduced, and used to make sugars, starch, and to regenerate RuBP, the CO_2-acceptor molecule. An overall diagram of the process is shown in Figure 3., illustrating the stomata, the problem of water loss, and the sources of energy that make the photosynthetic cycle run. This cycle is known as the C_3 cycle, because the first product of carboxylation is a C_3 compound. It is also known as the Calvin cycle, after its discoverer.

Certain plants have developed a special technique to enable them to live in extremely dry environments. Cacti can survive under conditions where ordinary plants would die. They take advantage of the fact that, although it may be very hot and dry in the daytime, it is often cool and quite moist at night. Their photosynthetic metabolism uses a different

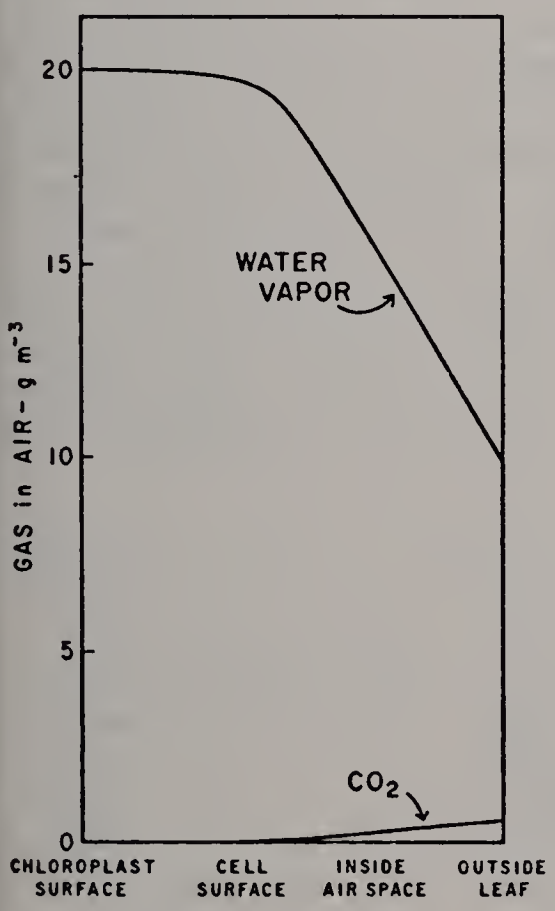


Fig 1. Diffusion gradients of water and carbon dioxide.

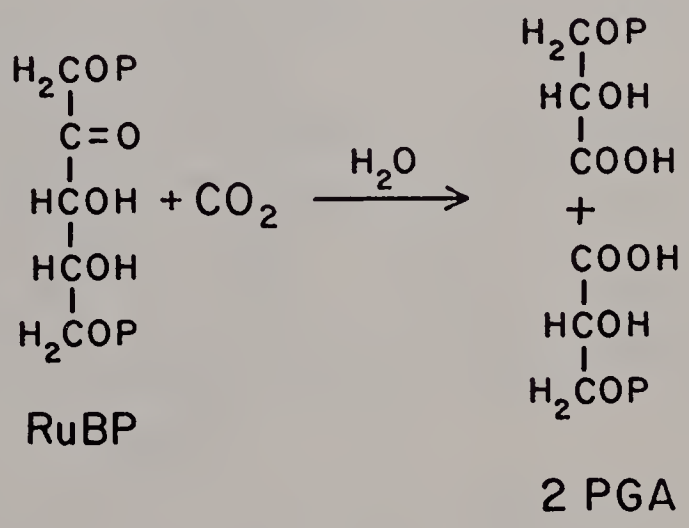
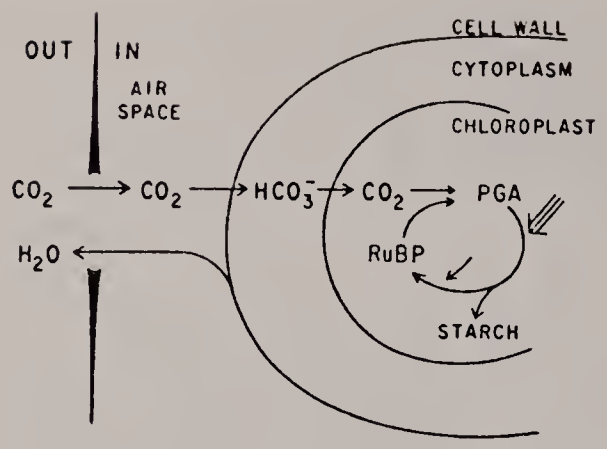


Fig 2. Ribulose bisphosphate carboxylase (RuBPcase).



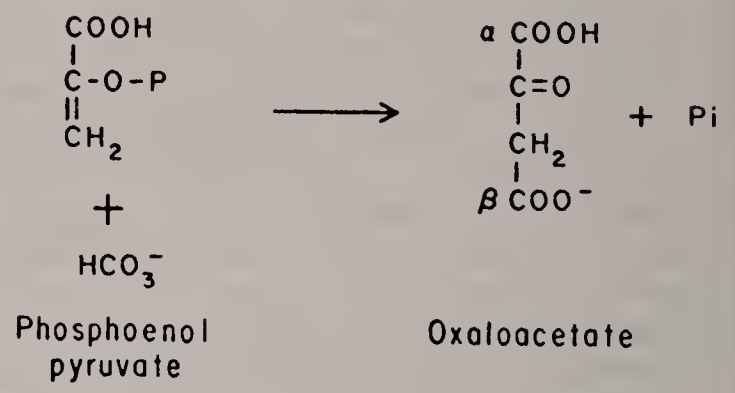


Fig 4. Phosphonenol pyruvate carboxylase (PEPcase).

Fig 3. Outline of C_3 photosynthesis; arrows indicate input of light energy.

primary carboxylase, called phosphenol pyruvate carboxylase (PEPcase), whose function is shown in Figure 4. This carboxylase uses bicarbonate (which is hydrated CO_2) instead of CO_2 as a substrate. The operation of this kind of photosynthesis, called Crassulacean Acid Metabolism (CAM) because it is characteristic in crassulacean plants, is shown in Figure 5. At night the stomata are open, the plants absorb CO_2 which is fixed by PEPcase with the manufacture of organic acids which build up in the plant. The substrate, PEP, is formed from the breakdown of starch that was made in the previous day's photosynthesis.

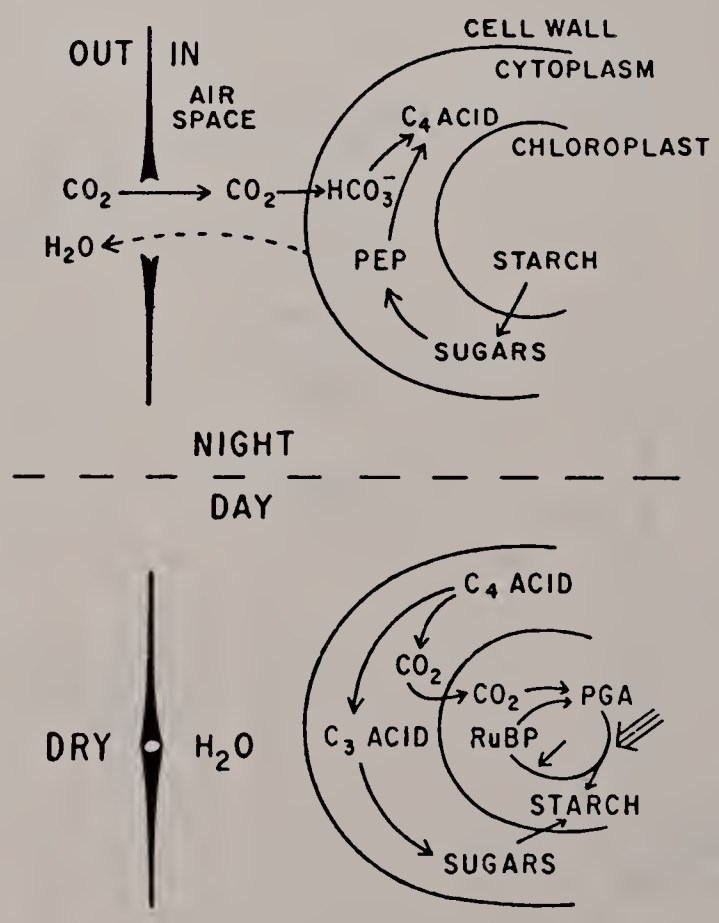


Fig 5. Outline of Crassulacean Acid Metabolism (CAM).

During the day, the stomata close to prevent water loss. Then all the acids that were formed the previous night are again decarboxylated, and the CO_2 so produced is fixed photosynthetically by RuBPc'ase in the usual way. The C_3 compound formed from the decarboxylation of the C_4 acids can also be made into sugars or starch, and is not wasted. CAM metabolism is not very fast, but it does enable the plant to survive under extreme conditions of drought. It may be so dry that the stomata can never open, day or night, for a period of months. This would kill ordinary plants because they would lose weight by respiration and eventually die. CAM plants, however, are able to refix any respiratory CO_2 that they lose, and so can survive even if they cannot grow.

A different problem is oxygen. I mentioned earlier that oxygen is poisonous. It turns out that RuBPcase is a 'short sighted' enzyme and is unable to distinguish easily between oxygen and CO_2. It evolved early in geological times when there was a lot of CO_2 and very little oxygen in the atmosphere, so that this characteristic of the enzyme was not important. However, during earlier eras plants behaved in a profligate manner and used up all their raw materials and poisoned the environment with their by-products (oxygen). In this respect they resemble the behavior of some more recent biological systems! Thus, the carboxylase also functions as an oxygenase. and when it fixes oxygen it makes one molecule of PGA and one molecule of a C_2 compound called glycolic acid, instead of two molecules of PGA (Fig 6). Glycolate is not of much use to the plant, but a C_2 cycle has evolved which enables the plant to trap much of the wasted glycolate and feed it back into the system (Fig 7). In this way, three-quarters of the carbon passing into glycolate (which may amount to a large proportion to total photosynthate) is salvaged and fed back in as PGA to the Calvin cycle. This helps, but the process, called photorespiration (because oxygen is consumed and CO_2 is produced in light), is very wasteful. Now PEPcase, which I described in connection with CAM metabolism, absorbs bicarbonate (HCO_3^-) instead of CO_2 and consequently has no problem with oxygen. An enzyme that recognizes bicarbonate has no difficulty in distinguishing between bicarbonate and oxygen. Certain plants have evolved a mechanism that uses this enzyme, PEPcase, to pump CO_2 into the inside of the leaf. This has two effects: oxygen ceases to be a problem to the initial carboxylase, which can thus absorb CO_2 readily, and CO_2 can be oncentrated inside the leaf where it can then be fixed much more effectively by RuBPcase. In a sense, this is rather like throwing a football: if you

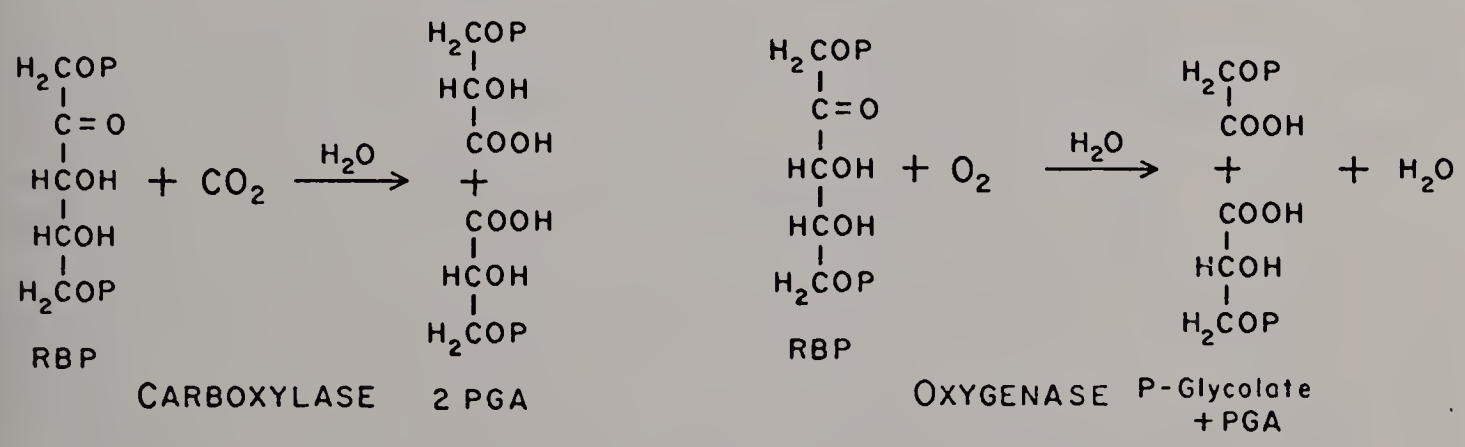


Fig 6. Ribulose bisphosphate oxygenase (RuBPcase).

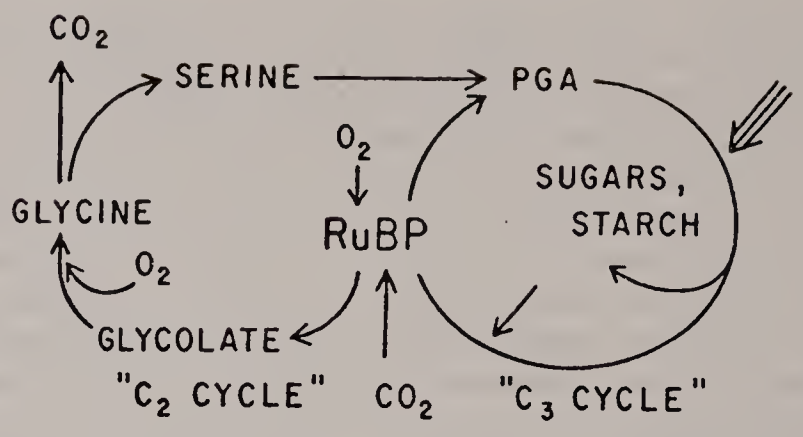


Fig 7. Outline of the C_2 cycle of photorespiration.

want to throw a handful of air from one place to another, the easiest way to do so is to wrap it up in a leather skin and throw that. In the same way, CO_2 is 'wrapped up' by being fastened onto a C_3 compound, PEP, to make a C_4 acid which can be 'thrown much more readily to the inside of the plant. Since first product of this kind of photosynthesis is a C_4 acid, it is called C_4 photosynthesis.

C_4 photosynthesis is shown in Figure 8. Carbon is fixed by PEP carboxylase in mesophyll cells (see Fig 14) and is then transferred, in the form of C_4 acids, to the bundle-sheath cells (cells that surround the vascular tissue) where it is released by decarboxylation of the C_4 acid and fixed by RuBPcase. The system thus requires cooperation between two cell types. In a conventional leaf there are considerable open spaces, and a long diffusion path that CO_2 must travel before it is picked up by the photosynthetic cells. In a C_4 leaf the air spaces are much smaller, the mesophyll more dense, and there is a pronounced ring of cells around each vascular bundle where the final carbon fixation takes place. This anatomical structure (called Kranz anatomy) is essential for effective operation of the C-$_4$ cycle. C-$_4$ plants usually have higher productivity (such as corn, sorghum, sugar cane, and a number of extremely persistent weeds such as fox grass, bermuda grass and crab

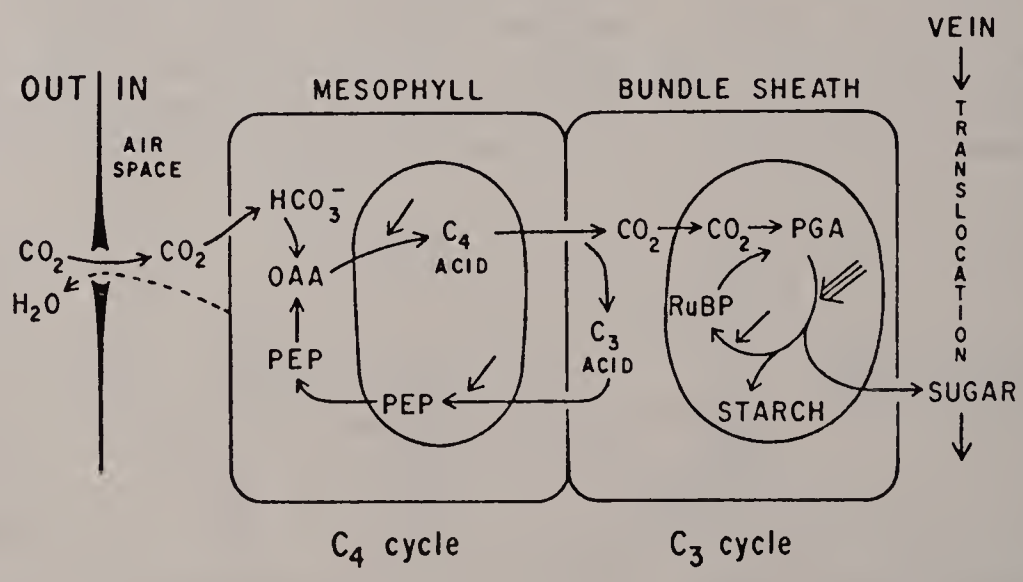


Fig 8. Outline of C_4 photosynthesis - integration of the C_4 (Hatch and Slack) cycle and the C_3 (Calvin) cycle; arrows indicate input of light energy.

grass) because they can make better use of carbon in bright light and under conditions when there is a shortage of water. They require some additional energy input to drive the C-$_4$ cycle, but this is more than offset by the fact that PEPc'ase is a much more effective CO_2 trap, that the CO_2 has a much shorter diffusion pathway and so enters the leaf more quickly, and (because the C_4 cycle works well at low CO_2 concentration) the stomata need not open so widely and less water is lost. These plants, therefore, are able to function effectively under drought conditions that would stop a C_3 plant. Ultimately, of course, the productivity of the plant depends on the RuBPcase. In optimum conditions, C_3 plants may photosynthesize as rapidly as C-$_4$ plants, and be just as productive. C_4 plants, however, are usually more effective because they can get ahead in hot dry weather when C_3 plants would have to shut down.

I shall now briefly consider seaweeds. They are important for food and for the chemical industry. In Nova Scotia, following the development of an experimental technology at ARL under Dr Neish and Dr Simpson, a number of industrial research stations have been developed for growing Chondrus and other seaweeds. The problem facing seaweeds is, of course, not water, but low CO_2, and its slow diffusion into and through seawater.

I worked at ARL last year on the gas exchange of seaweeds, which was measured with an infrared-gas analysis apparatus. It was necessary to measure CO_2 exchange in these plants in air because the sea contains large amounts of bicarbonate, which tends to equilibrate more or less rapidly with CO_2. It is virtually impossible to measure photosynthesis effectively, without very special precautions, when the plants are under water. With this apparatus, it was possible for the first time to make effective measurements of gas exchange in underwater plants. We noted at first that there is no effect of oxygen on the photosynthesis of marine plants, and they do not exhibit photorespiration. These are characteristics of C_4 plants. However we quickly found that although the plants were capable of some C_4 carboxylation, they did not contain a C_4 cycle. Kinetic analyses showed that the C_4 compounds formed in the light were not reused, and their carbon did not enter the C_4 cycle. Other data from Australia suggest that marine plants have the same carboxylase - a normal RuBPcase. Since the carboxylase is susceptible to oxygen poisoning, it follows that these plants must have some alternative method for concentrating CO_2. The only way that the oxygen effect can be prevented in a plant having normal RuBPcase is to present the carboxylase with a high enough concentration of CO_2 that the oxygen can no longer compete. We considered the possibility that such a CO_2-concentrating mechanism might be based on the bicarbonate in the sea. The sea contains a great deal of bicarbonate: its concentration is 2 mM, as compared to an equivalent concentration of 10μM for CO_2. There is, in other words, 200 times more bicarbonate around than CO_2.

CO_2 uptake by seaweeds appears normal (Fig 9) but, if the CO_2 concentration is increased to unusually high levels, an anomalous curve appears (Fig 10). Normally, photosynthesis increases at a more or less steady rate with increasing CO_2 concentration until a CO_2 concentration is reached at which the plant can handle no more. Then the curve flattens out. The curve in Figure 10 is quite different from this. We then, by careful manipulation, measured the rate of photosynthesis as

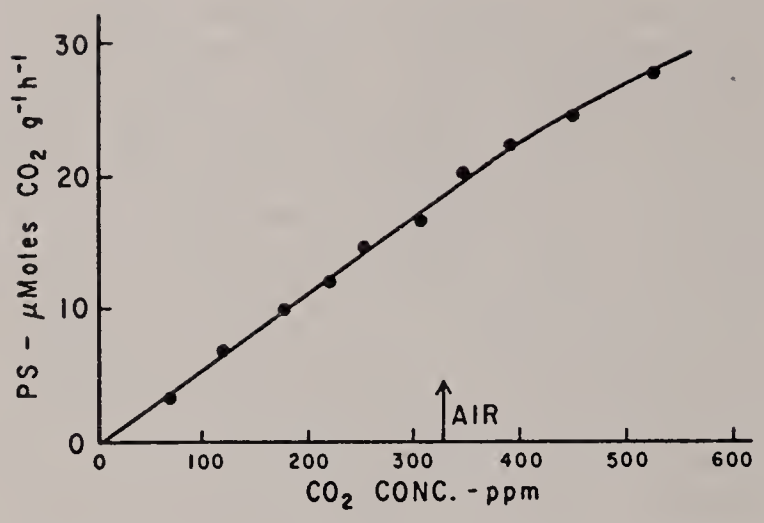


Fig 9. Photosynthesis of Fucus vesiculosus at low and normal concentrations of CO_2 in air.

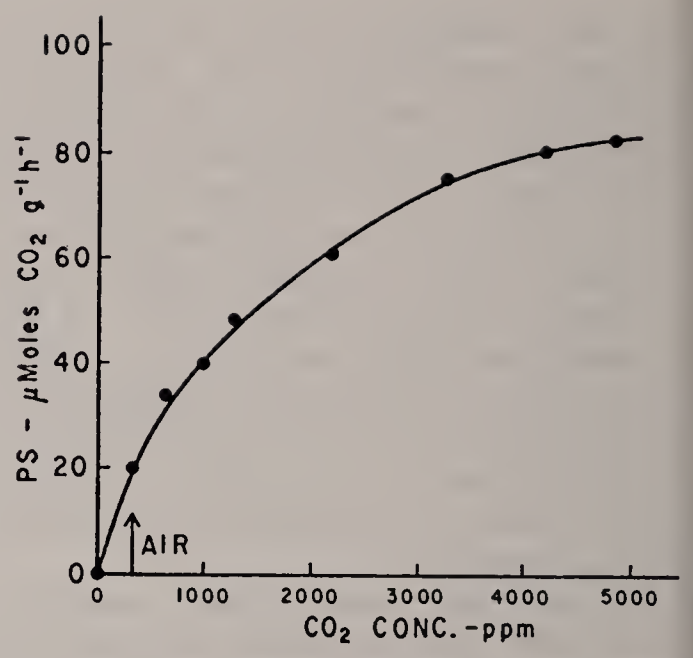
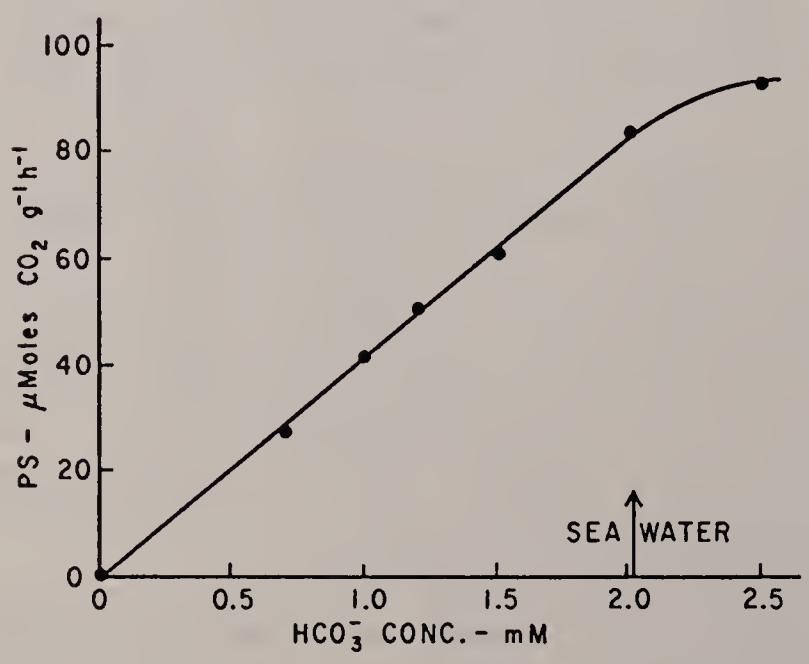


Fig 10. Photosynthesis of Fucus vesiculosus at elevated concentrations of CO_2 in air.

affected by the concentration of bicarbonate, and found that we got an absolutely normal curve (Fig 11) that levels off at a bicarbonate concentration slightly above that in seawater. In another experiment, bicarbonate was varied by varying the pH (Fig 12). You can see quite clearly that photosynthesis of this seaweed varied with the bicarbonate content and not the CO_2 content. From this and much other data that I am not

Fig 11. Photosynthesis of Fucus vesiculosus at low to normal concentrations of bicarbonate in seawater.



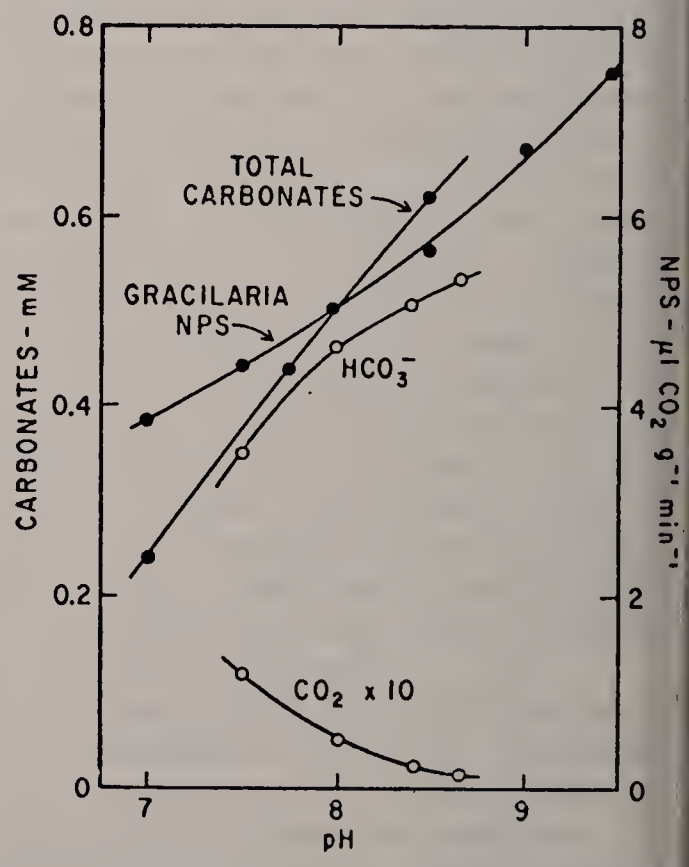


Fig 12. Photosynthesis of Gracilaria tikvahiae compared with bicarbonate [HCO_3^-] and CO_2 concentrations varied by pH.

presenting here, we conclude that these marine plants absorb bicarbonate rather than CO_2. This finally settles a long standing controversy, which could not have been solved without the use of the technology that we have developed for studying CO_2 exchange in underwater plants.

The next question to be answered is how do the plants use bicarbonate. Bicarbonate is a charged ion, which can be absorbed and pumped (it has a handle, its ionic charge, and is like the football analogy that I made earlier - it can be picked up and thrown to another place, which CO_2 cannot). Work in Canberra, Australia and in Toronto supports the fact that there is a mechanism in underwater plants that enables them to pump bicarbonate into the cell. Bicarbonate can diffuse through the cytoplasm to the chloroplast. Since the cytoplasm has about the same pH as seawater, there will be little tendency for the bicarbonate to convert to CO_2 until it reaches the chloroplast. There it encounters an enzyme, carbonic anhydrase, which greatly speeds the interconversion of bicarbonate and CO_2. In addition, the chloroplast has a lower pH than the cytoplasm. Both these facts favor the conversion of bicarbonate into CO_2. This will permit the buildup of a substantial concentration of CO_2 in or at the chloroplast - the same trick as performed by the C_4 cycle in C_4 plants, with the same result. Calculations of the bicarbonate and CO_2 concentrations in various plants are shown in Table I.

Table I Estimated bicarbonate and CO_2 concentrations inside leaves, fronds and cells of terrestrial and marine plants

		$CO_2 + HCO_3$ conc	
		HCO_3^- mM	CO_2 ppm
Air .		-	330
Inside leaf	C_3	-	50
air space	C_4	-	5-50
In chloroplast	C_3	-	2-5*
at RuBPcase	C_4	-	300-600*
Seawater		2	330 (10μM)
Algal cytoplasm		1.5	-
Algal chloroplast		-	150-300*

*Estimated value.

It can be seen that the calculated CO_2 concentration inside or at the chloroplast of algae is in the same range as that in C_4 plants, and much higher than that in C_3 plants. This, then, explains how algae can have a high rate of photosynthesis (they are among the most productive plants in the world), no photorespiration, and no poisonous oxygen effect.

Thus seaweeds have also learned a trick or two. In fact, it is possible that land plants also use a bicarbonate-transfer mechanism to move carbon through the mesophyll cells to photosynthetic sites. This would explain the almost universal presence of carbonic anhydrase in photosynthetic cells. Land plants would be foolish if they did not use

such a mechanism! It is much easier, if you want to kick air from one place to another, to wrap it up!

Seaweeds may not be so beautiful as some land plants, but beauty may be more than skin deep. The photosynthetic mechanisms under the epidermis of CAM and C_4 plants, and also of the seaweeds, are really rather beautiful. That, after all, is how plants make plants.

THE SECOND A. C. NEISH MEMORIAL LECTURE

INTRODUCTION OF A. W. GALSTON

J. E. BLANCHARD*

We are pleased to have Dr Arthur Galston as the speaker for the second A. C. Neish Memorial Lecture. Dr Galston is the Eaton Professor of Botany at Yale University. He studied at Cornell and Illinois before joining the Navy in 1944, becoming the Agricultural Officer in the U.S. Military Government at Okinawa. He then worked at the California Institute of Technology and at Yale on the physiology of plants, particularly on plant hormones and the mechanisms of light and hormonal control of plant growth. He is the author of 218 scientific papers and the author or co-author of books on plant physiology and on Daily Life in People's China. He is a regular contributor to the Natural History Magazine and a member of the editorial boards of three scientific journals. Dr. Galston was among the first American scientists in 1971 to visit the People's Republic of China, and had interviews with Premiers Chou En-Lai (China), Pham Van Dong (North Vietnam) and Norodom Sihanouk (Cambodia). He has had an opportunity to travel in Vietnam and to make observations on effects of the extensive use of defoliants. Ladies and Gentlemen, it is my pleasure to introduce Dr Galston whose lecture, 'Science and Social Concern', will draw from his experiences in plant physiology.

*Chairman, A.C. Neish Memorial Trust.

SCIENCE AND SOCIAL CONCERN, A CASE HISTORY FROM PLANT PHYSIOLOGY

A. W. GALSTON

I have long been an admirer of the late Dr A. C. Neish, and I wish to record my feeling of deep pride and honor at having been asked to deliver the Second A. C. Neish Memorial Lecture at Dalhousie University on October 12th 1977.

This paper, subtitled 'The Devilish Dioxins', omits many personal remarks which I made to explain my involvement in the social consequences of scientific research. These details have been published several times previously, and the interested reader can find them in Galston (1972)*.

One of our most widely used herbicides, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), carries within it a trace impurity with the potential to cause mutations, human cancer, and various fetal malformations. Although the impurity is generally present in what appears to be vanishingly small quantities, such as 0.1 part per million in the best preparations, it is still abundant enough to cause trouble. Dr J. R. Allen, of the University of Wisconsin Medical School's Department of Pathology has found that as little as 5 parts per trillion in the diet of a rat over an 18-mo period can cause the appearance of some cancers, and the incidence rises steadily with increasing dosage. Among the cancer types reported are adenocarcinoma of the kidney, angiosarcoma and malignant histiocytomas. In non-human primates, 500 parts per trillion of the impurity in the diet for a period of nine months produced mortality in over 50% of the exposed animals, death generally occurring from a marked diminution in red and white blood cells. Thus, even a million-fold dilution of the original herbicide would still produce toxic effects. Previously, Dr W. T. Jackson of Dartmouth College had found 2,4,5-T and its impurity to cause chromosome breakage in dividing plant cells.

The offending impurity, called TCDD or dioxin for short, is 2,3,7,8-tetrachloro-para-dibenzodioxin. It is formed almost inevitably as a trace side product when the herbicide 2,4,5-T is synthesized from two simple starting materials, 2,4,5-trichlorophenol and iodoacetic acid (Fig 1). In the normal reaction, the acetic acid hooks on to the oxygen of the phenol, forming the 2,4,5-T in one simple coupling reaction. In the alkaline medium employed for the reaction, that hydriodic acid split out of the two reactants during the coupling is neutralized to sodium iodide.

During the Vietnam war, when large quantities of 2,4,5-T were manufactured for use as a defoliant, synthetic facilities were strained, and attempts were made to speed up production by the simple expedient of raising the temperature of the reaction vessel. Under these conditions, an undesired side reaction occurred, in which two of the phenolic reactants united with each other, giving rise to the dioxin (Fig 2).

*Galston, A. W. 1972. Science and social responsibility: A case history. Ann. N.Y. Acad. Sci. 196: 223-35.

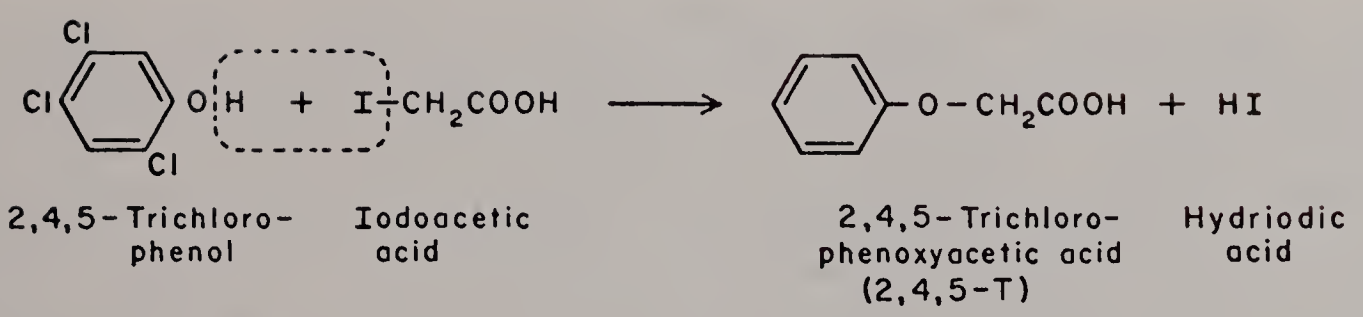


Fig 1. Synthesis of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T).

Some dioxin is also apparently generated during hydrolysis of trichlorobenzene to form the phenol. In some preparations available commercially in the late 1960's, as much as 25 parts per million of the TCDD were present, although the best preparations at the time contained more like 1 part per million. So, inadvertently, a poisonous contaminant was dispensed with the herbicide.

Like all chemical compounds designed for use in large scale agriculture, the phenoxyacetic acids had been tested for toxicity and found to be innocuous. But those tests, conducted in the immediate post-World War II era when the herbicides were first developed, are now regarded as inadequate. The trials were never carried out for long enough periods of time to detect the tumorous transformations, nor were offspring examined, making impossible the detection of genetic aberrations and fetal malformations. The latter, referred to as teratogenic effects, were first picked up in 1969, when the Bionetics Laboratories in Maryland, under federal contract, supplied the Surgeon General of the United States with information that ultimately led the then Presidential Science Advisor, Dr Lee DuBridge, to suggest a temporary ban on the use of 2,4,5-T. The ban has, over the years, been partially lifted, and the United States Forest Service, a branch of the Department of Agriculture, regularly uses the compound as an aerial spray to thin forests. This practice has not gone unchallenged, and there are currently some lawsuits in the courts in which citizens are seeking recompense for alleged damage to their plants, animals and themselves. Since the Forest Service plans to continue using the compound, this kind of litigation is bound to increase. And since recent tests in Sweden and the United States have documented the carcinogenicity and mutagenicity of TCDD, some of these lawsuits may be successful.

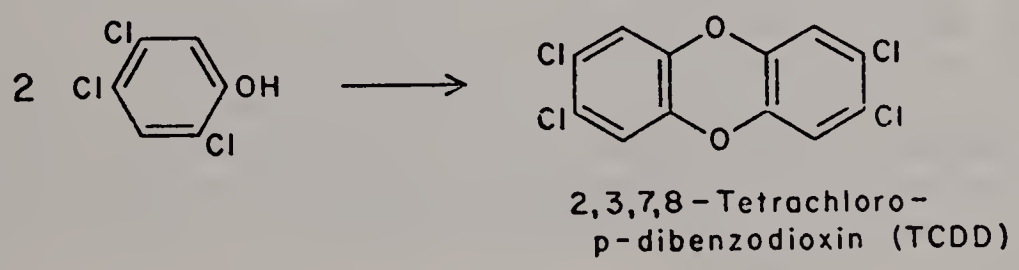


Fig 2. Formation of 2,3,7,8,-tetrachloro-p-dibenzodioxin (TCDD) through a side reaction.

In the spring of 1970, I accompanied then Congressman Richard D. (Max) McCarthy of Buffalo to Globe, Arizona, where an aroused group of citizens was protesting an aerial herbicide spray program that they felt was endangering their health and property. McCarthy, an improbable Democrat from a heavily Republican area, had concerned himself especially with problems of chemical and biological warfare, and had thus focused on herbicides because of their massive use in Vietnam. McCarthy's hearings revealed that the Forest Service aerially sprayed portions of the Tonto National Forest to kill 'unwanted' vegetation. The aim of the operation was really to decrease the amount of water evaporated by those trees in the process of transpiration; killing the trees would thus increase runoff into streams that ultimately fed into the water supply for rapidly growing Phoenix. This is obviously a potentially adversary situation, in which pressures of all kinds might be brought to bear on regulatory agencies. Unhappily, the borders of the National Forest wander into and out of residential areas of Globe, and this, together with some carelessness in operation, led to drift of the droplets of the sprayed herbicide onto private property. Damage of various kinds, to plants, domestic animals and humans was claimed, and the courts will shortly have to evaluate the validity of the allegations. In the meantime, other incidents of the same sort have cropped up, but the Forest Service, undeterred, proposes to continue its spray program into the future.

A few years ago, Robert Baughman and Matthew Meselson at Harvard devised an improved method for the detection of minute traces of TCDD and related dioxins. Based on the use of gas chromatography, their method was able to detect and measure dioxins in materials previously considered dioxin-free. Using this technique, Meselson and his colleague O'Keefe have now found traces of dioxins in samples of human mothers' milk obtained from Texas and Oregon, where previous spray operations had occurred. This finding, if substantiated, would indicate that the dioxins may find their way into the human environment, with possible effects on human health. Whether the dioxins are absorbed by plants, passed on to animals, and accumulated during passage up the biological food chain is unknown, but given the example of DDT, this possibility cannot be overlooked.

The intrusion of dioxins into our lives is not limited to operations involving herbicides. The recent explosion of a chemical plant in Seveso, Italy is a case in point. This factory was employing chlorinated phenols in synthetic operations, but the explosion, causing the release of many products into the atmosphere and ground, alarmed those who knew about the danger of dioxins. Many workers in such factories had previously contracted chloracne, a serious skin irritation, and other troubles were suspected as well. So gravely did the government view the incident that it evacuated the town and sealed off the area. Presented with the evidence on dioxin-caused fetal aberrations, the Catholic hierarchy gave permission for rarely sanctioned abortions. The town remains uninhabited, and given the persistence of dioxins, may remain so for a long time. Given the widespread use of chlorinated phenols in the chemical industry and wood preservation, additional accidents and incidents are sure to occur.

In Vietnam, where an estimated 550 lbs of dioxins were inadvertently deposited along with the herbicidal "Agent Orange" (a mixture of

esters of 2,4-D and 2,4,5-T in a barrel with an Orange stripe), there have been reports of some unusual health problems. Dr Ton That Tung, the distinguished and internationally recognized surgeon who heads the Viet Duc hospital in Hanoi, is struck by the fact that primary cancer of the liver, formerly an unimportant cause of death in Vietnam, has now risen to second place in the list of cancer-related mortalities. Many of the cases he treated in the north of his country involved people who had been in the south, where the bulk of the spray operations had occurred. He also points to the prevailing south-to-north currents off the coast as a possible means of bringing to the populated areas of the north residues washed into the waters from the zone of deposition in the south. Dioxin residues have been detected in fish and shellfish long after the defoliation program ceased and Vietnamese consume such foods as their major source of protein. There is no certain linkage between TCDD and health problems in Vietnam, but Dr Tung points out that the liver is a likely locale for the body to send TCDD for decontamination.

In the light of these facts, it comes as a bit of a surprise to learn that the United States Forest Service, undeterred by the medical findings, proposes to continue its 2,4,5-T spray program in the northwest. Citizens groups of various kinds are banding together to fight this plan, and some scientists are giving their opinions in advance of the start of operations. Certainly, the Environmental Protection Agency as well as other governmental bodies must get into the act before long. It will be interesting to see what policy is eventually adopted; the decision is certain to reflect sharply the division between the environmentalists, for whom preservation of health and ecological balance is paramount, and the technocratic types, who want the facilitation of productive processes to be the decisive issue.

Whatever happens with 2,4,5-T, there is certain to be some concerned reappraisal of that long-time standard herbicide, 2,4-D. Long used to kill dicotyledonous broadleaved weeds in a field of monocotyledonous plants, this herbicide is a component of virtually every spray designed to rid lawns of such 'offensive' weeds as dandelion and plantain. Is there danger from dioxins in 2,4-D preparations as well? After all, they are synthesized from chlorinated phenols, and might, therefore, undergo the same side reactions. The evidence so far appears to give 2,4-D a relatively clean bill of health. The same Bionetics Laboratory test that found 2,4,5-T to be teratogenic did show some slight activity with 2,4-D as well, but the samples used in that test were extraordinarily contaminated by modern standards. Also the tendency to form dioxins seems to be diminished when there are fewer chlorine atoms in the ring, and the resulting dioxins are much less toxic than the 2,3,7,8-tetrachloro-derivative formed during the synthesis of 2,4,5-T. Nonetheless, careful tests for mutagenicity and carcinogenicity must be carried out with this compound as well, for like 2,4,5-T, it came into use at a time when toxicological tests were much less stringent than we now know they should be. A decision to limit or terminate the use of 2,4-D would have widespread consequences, not only for present agricultural practice, but also for the willingness of manufacturers to enter on the risky road to the production of a new herbicide.

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AN ANNOTATED LIST OF THE MACROLEPIDOPTERA OF SABLE ISLAND

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A list of 58 species of Macrolepidoptera is presented, representing 2 families of butterflies and 4 families of moths collected on Sable Island in 1976 and 1977. The month(s) when the species was collected, the number of specimens collected, and data on larval food plants and ecological notes also are given.

INTRODUCTION

During the summers of 1976 and 1977, extensive field work on Sable Island by Barry Wright of the Nova Scotia Museum of Science has greatly increased the knowledge of the Lepidoptera of this island. Collecting was done intermittently from early June to early October of both years using standard entomological techniques, including light trapping, sugaring, and diurnal collecting using nets and collecting jars. These methods have produced a list of Macrolepidoptera of Sable Island sufficiently complete as a basis for further work on, for example, faunal changes in the future.

Sable Island had been largely neglected entomologically chiefly because of its isolation and inaccesibility. Ferguson (1955) lists only one species of Macrolepidoptera, Ommatostola lintneri Grt. (Noctuidae), as occurring on the island, based on a specimen collected in 1899. In 1966, E.W. Rockburne and D.F. Hardwick of the Biosystematics Research Institute, Department of Agriculture, Ottawa, under the auspices of the National Museum of Natural Science, extensively collected on Sable Island. They listed 23 species of Macrolepidoptera representing two families of moths, the Arctiidae and Noctuidae as occurring on Sable Island (in Howden et al 1970).

The present study lists 58 species of Macrolepidoptera, representing 2 families of butterflies and 4 families of moths. All species listed by Rockburne and Hardwick in 1970 have been obtained in the most recent collections except for 2: Amphipoea interoceanica Sm. (Noctuidae), and Polia pulverulente Sm. (Noctuidae), the first probably having been misdetermined for the closely related Amphipoea americana Speyer (Noctuidae) which is moderately common on Sable Island. All species collected in this study have been previously collected from the mainland, although as will be indicated, some may yet prove to be specifically distinct.

Species listed here follow the arrangements in McDunnough (1938), using the taxonomy proposed chiefly by Forbes (1954) and various other writers. Botanical names follow those used by Roland and Smith (1969).

After each species, an estimate of abundance and the actual number, in parentheses, of specimens collected is given. The month(s) when the species was collected and any data on host plants of the larvae, ecological notes, or other relevant information concerning the species on Sable Island are given.

I thank Barry Wright of the Nova Scotia Museum for providing me with all the material collected on Sable Island in the past 2 yr and for his helpful comments and suggestions in the writing of this paper.

SPECIES LIST

Pieridae

Colias philodice (Godt.) Rare (1), June. A single female collected near West Light.

Nymphalidae

Vanessa virginiensis (Dru.) Rare (2), July and September. Probably common some years throughout the summer months; larvae observed feeding on pearly everlasting (Anaphalis margaritacea L.).

Sphingidae

Sphinx gordius (Cram.) Moderately common (16), June and July. Bred from ova on bayberry (Myrica pensylvanica Loissel.), the only host the larvae would accept.

Arctiidae

Diacrisia virginica (Fabr.) Moderately common (14), June and July. Bred from pupae found under boards near the New Main Station.

Noctuidae

Euxoa detersa (Wlk.) Abundant (69), August and September. One of the most common moths on Sable Island, but considered rare on the mainland.

Euxoa scandens (Riley) Abundant (38), July and August.

Euxoa messoria (Harr.) (?) Uncommon (5), September. Quite different in general coloration from the mainland E. messoria, and may eventually prove to be another species.

Agrotis venerablis Wlk. Rare (1), September. Collected at a light trap near the Meteorological Station.

Agrotis sp Uncommon (7), June and July. This species, which resembles no other Agrotis species found in Nova Scotia, has markings similar to A. volubilis Harv., but has the ground color replaced by a light-brownish shade.

Spaelotis clandestina (Harr.) Rare (1). The exact date of capture, 15 June 1977, is rather early for this species which occurs on the mainland from early July to mid-August (Ferguson 1955).

Eurois occulta (L.) Moderately common (13), July.

Ochropleura plecta (L.) Rare (1), September. Probably more common on Sable Island than these collections suggest, as this species is very common on the mainland, and is well represented in the earlier collections (Howden et al 1970).

Peridroma saucia (Hbn.) Rare (2), June. Another species which is more than likely quite common on the island than the records indicate.

Heptagrotis phyllophora (Grt.) Abundant (30), July.

Amathes c-nigrum (L.) Abundant (52), July. One of the more common species on Sable Island.

Amathes smithi (Snell.) Moderately common (16), September.

Rhynchagrotis cupida f brunneipennis (Grt.) Rare (2), September. Two specimens taken, one on 8 September 1977, the other on 12 September 1977, were both rather late for this species, the latest date of capture on the mainland being 2 September (Ferguson 1955).

Lacinipolia renigera (Steph.) Moderately common (14), July to September.

Lacinipolia lorea (Gn.) Rare (3), June and July. Rockburne and Hardwick (in Howden et al 1970) list this as one of the more common species on the island.

Nephelodes minians Gn. Abundant (31), September.

Faronta diffusa (Wlk.) Moderately common (13), June. This species is recorded by Ferguson (1955) as being double brooded on the mainland, but appears to be only single brooded on Sable Island.

Pseudaletia unipuncta (Haw.) Abundant (25), April to July.

Aletia oxygala (Grt.) Abundant (49), June and July.

Xylena nupera (Lint.) Rare (1), May.

Apamea amputatrix (Fitch.) Rare (1), July.

Apamea inordinata (Morr.) Moderately common (9), June. Quite scarce on the mainland, but apparently more common on Sable Island.

Apamea finitima (Gn.) Abundant (22), June.

Crymodes devastator (Brace) Abundant (25), June to September. A notorious cutworm on the mainland.

Protoagrotis niveivenosa (Grt.) Rare (2), July. A rare species throughout Nova Scotia.

Oligia bridghami (G. & R.) Rare (3), August to September.

Oligia mactata (Gn.) Rare (1), September.

Spartinophaga inops (Grt.) Rare (1), August.

Ommatostola lintneri (Grt.) Moderately common (11), July and August. Local on the mainland, being restricted to sand dunes and beaches; until 1966 this was the only species of lepidopteran recorded from Sable Island (Ferguson 1955).

Hypocoena sp Rare (1), September.

Helotropha reniformis (Grt.) Rare (1), August.

Amphipoea americana (Speyer) Moderately common (13), July and August. The closely related A. interoceanica (Sm.) recorded by Rockburne and Hardwick (in Howden et al 1970) has not been collected in the recent study, and was probably recorded in error by them for A. americana.

Papaipema sp (?) Rare (1), September.

Proxenus miranda (Grt.) Abundant (24), July. A species common on bogs and marshy areas on the mainland.

Galgula partita (Gn.) Rare (1), August.

Spodoptera frugiperda (J. E. Smith) rare (1), September.

Enargia infumata (Grt.) Rare (1), September. Collected by day as it flew over the dunes in the vicinity of the Meteorological Station.

Helicoverpa zea (Boddie) Uncommon (6), August and September.

Syngrapha rectangula (Kby.) Rare (1), July.

Syngrapha octoscripta (Grt.) Rare (1) September.

Autographa precationis (Gn.) Rare (2), July to September. The only plusiid previously recorded from Sable Island (Rockburne & Hardwick in Howden et al 1970).

Plusia aereoides (Grt.) Uncommon (6), July.

Catocala unijuga (Wlk.) Rare (1), July.

Caenurgina erechtea (Cram.) Rare (1), August. A common open grassland species on the mainland, and will probably prove to be more common on Sable Island.

Anticarsia gemmatilis (Hbn.) Rare (1), September. A southern migrant, coming north in the autumn.

Hypena humuli (Harr.) Rare (2), July. A rather early record for this species which is common on the mainland from September to October (Ferguson 1955).

Liparidae

Orgyia leucostigma placiata (Wlk.) Abundant (47), July to September. Larvae collected from blueberry (Vaccinium sp), iris (Iris versicolor L.), bayberry (Myrica pensylvanica Loisel), grasses, sedges, and rushes; morphological differences from mainland specimens have been observed in both larvae and adults from Sable Island, and this could eventually prove to be a different species.

Geometridae

Heliothis obsoleta (Fabr.) Uncommon (6), August and September.

Syngrapha rectangula (Kby.) Rare (1), July.

Syngrapha octoscripta (Grt.) Rare (1) September.

Autographa precationis (Gn.) Rare (2), July to September. The only plusiid previously recorded from Sable Island (Rockburne & Hardwick in Howden et al 1970).

Plusia aereoides (Grt.) Uncommon (6), July.

Catocala unijuga (Wlk.) Rare (1), July.

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Liparidae

Orgyia leucostigma A. & S. Abundant (47), July to September. Larvae collected from blueberry (Vaccinium sp), iris (Iris versicolor L.), bayberry (Myrica pensylvanica Loisel), grasses, sedges, and rushes; morphological differences from mainland specimens have been observed in both larvae and adults from Sable Island, and this could eventually prove to be a different species.

Geometridae

Nemoria rubrifrontaria (Pack.) Rare (3), June and July.

Mesothea incertata (Wlk.) Rare (5), June. Collected by day flying over the dunes in the vicinity of the Old Main Station.

Cyclophora pendulinaria (Gn.) Rare (1), July.

Pleuroprucha insularia (Gn.) Rare (1), July.

Eulythis testa (L.) Moderately common (12), September.

Eulythis explanata (Wlk.) Rare (2), July.

Eupithecia sobrinata interruptofasciata (Pack.) Rare (1), September.

REFERENCES

FERGUSON, D.C. 1955. The Lepidoptera of Nova Scotia: Part I (Macrolepidoptera): Nova Scotia Mus. Sci. Bull. 2: 1-214.

FORBES, W.T.M., 1954. The Lepidoptera of New York and neighboring states. Part III. Mem. Cornell Univ. Agric. Expt. Sta. No. 329: 1-433.

HOWDEN, H.F., MARTIN, J.E.H., BOUSFIELD, E.L., and MCALLISTER D.E. 1970. Fauna of Sable Island and its zoogeographic affinities - a compendium: Nat. Mus. Natl. Sci. Publ. Zool. No. 4: 1-45.

MCDUNNOUGH, J.H. 1938. A check list of the Lepidoptera of Canada and the United States of America. Part I, Vol. I, (Macrolepidoptera). So. Calif. Acad. Sci. Mem: 1-275.

ROLAND, E.A. and SMITH, E.C. 1969. The Flora of Nova Scotia. Nova Scotia Museum, Halifax, N.S.

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FATTY ACIDS IN SOME NOVA SCOTIAN MARINE SEAWEEDS: A SURVEY FOR OCTADECAPENTAENOIC AND OTHER BIOCHEMICALLY NOVEL FATTY ACIDS*

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The total fatty acids of 15 seaweeds from Nova Scotia were examined for unusual fatty acids by open-tubular gas-liquid chromatography. Several unknown fatty acids were detected, but the novel 3,6,9,12,15-octadecapentaenoic acid was not observed. Three species of Chlorophyceae showed cis-11-octadecenoic acid in proportions greater than the more common cis-9-octadecenoic isomer. The C_{20} acids with unsaturation in the Δ^5 position and in one or more of the Δ^{11}, Δ^{14}, or Δ^{17} positions were frequently observed in traces but were important (4%) in Ascophyllum nodosum. Agarum cribrosum, Porphyra leucosticta and A. nodosum showed unusual fatty acid features warranting further investigaton from a chemotaxonomic point of view.

INTRODUCTION

Seaweeds of numerous types are plentiful along the shores of Nova Scotia, but only a few species are exploited commercially, and then primarily for polysaccharides (Neish et al 1977). The recent discovery by Joseph (1975) of 18:5ω3 (all-cis 3,6,9,12,15-octadecapentaenoic acid)** as a major fatty acid in the unicellular alga Prorocentran minimum and later by Mayzaud et al (1976) in other dinoflagellates, was a development somewhat unexpected to lipid chemists. No precedent for a cis-ethylenic

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**A shorthand notation of chain length: number of ethylenic bonds will be used. This presumes that all bonds are cis, all are methylene-interrupted, and gives the position of the bond nearest to the terminal methyl group. The conventional system of numbering from the carboxyl group uses a Δ^2 notation and makes the same assumption unless otherwise indicated.

bond in the Δ^3 position of a polyunsaturated fatty acid existed. Although a precise biochemical pathway for the formation of this acid is not known, the simple pathway proposed by Joseph (1975) of chain shortening of 20:5ω3 (all-cis 5,8,11,14,17- eicosapentaenoic acid) suggested that 18:5ω3 might have been overlooked in seaweeds which are often rich in 20:5ω3. This report is of an examination of 15 common Nova Scotian seaweeds for 18:5ω3 and other novel marine fatty acids of possible commercial or scientific importance. Existing information of this type from the North Atlantic littoral (Chuecas & Riley 1966; Jamieson & Reid 1972b; Klenk et al 1963; Laur 1965; Wagner & Pohl 1965) is supplemented by details of isomers and other structures ascertained by open-tubular gas-liquid chromatographic technology. A brief report has appeared elsewhere (Ackman & McLachlan 1978).

MATERIALS and METHODS

Seaweeds were collected in various Nova Scotian localities in the autumn of 1977. The species, locations and dates are given in Table 1.

Table 1. Sample code, species, collection site, and date of collection.

Code No.	Species	Collection Site	Date
	Chlorophyceae		
20	Acrosiphonia arcta	Finck Cove, Hfx. Co.	15/2/77
19	Blidingia minima	Finck Cove, Hfx. Co.	15/2/77
	Phaeophyceae		
13	Agarum cribrosum	Paddy Head, Hfx. Co.	1/2/77
7	Alaria esculenta	Finck Cove, Hfx. Co.	6/12/77
3	Ascophyllum nodosum	Finck Cove, Hfx. Co.	29/11/77
4	Fucus vesiculosus	Finck Cove, Hfx. Co.	29/11/76
9	Laminaria digitata	Finck Cove, Hfx. Co.	6/12/77
15	Ralfsia fungiformis	Gulliver Cove, Digby Co.	7/2/77
	Rhodophyceae		
8	Chondrus crispus	Finck Cove, Hfx.Co.	6/12/76
17	Gigartina stellata	Gulliver Cove, Digby Co.	7/2/77
18	Halosaccion ramentaceum	Finck Cove, Hfx. Co.	15/2/77
10	Palmaria palmata	Finck Cove, Hfx. Co.	23/12/77
14	Polysiphonia lanosa	Paddy Head, Hfx. Co.	1/2/77
16	Porphyra leucosticta	Gulliver Cove, Digby Co.	7/2/77
11	Ptilota serrata	Finck Cove, Hfx. Co.	18/1/77

Species were separated, transported to the laboratory in plastic bags and ice, and frozen for storage prior to study, usually within a few weeks of collection. For analyses, samples were thawed slowly at room temperature and blotted free of seawater. All obvious foreign material was removed. The basic extraction technique employed was to

weigh 10 g of coarsely-chopped samples into a 250 ml round-bottomed standard-taper flask, add a solution of NaOH (0.5N) in MeOH (100 ml), and reflux under nitrogen for 2 h. After cooling, the solution was filtered through pre-rinsed (MeOH) coarse filter paper into a nitrogen-flushed 250 ml separating funnel containing distilled water (100 ml) and redistilled n-hexanes (50 ml). After shaking and allowing to clear, the bottom layer was drained into a second funnel (nitrogen-flush) containing n-hexanes (50 ml) and reextracted. The two n-hexane extracts of unsaponifiable materials were discarded. From the second extraction, the separated bottom layer was drained into a third funnel (nitrogen-flush) containing n-hexanes (50 ml), and concentrated HCl (approximately 5 ml) was added slowly with swirling of the separatory funnel. After allowing the contents to cool to room temperature under nitrogen, the mixture was vigorously shaken and checked for acidity. Any objectionable solids formed by acidification were removed by rapid filtration through coarse filter paper pre-rinsed with n-hexanes. Separation of the phases (overnight if convenient or necessary) was followed by a similar reextraction of the bottom aqueous phase. The combined n-hexanes phases recovered from the two extractions of acids were then washed (nitrogen) with distilled water in 50 ml lots until neutral. Any emulsion problems were controlled with a few drops of MeOH or of a saturated solution of Na_2SO_4. The final n-hexanes extract was dried over anhydrous Na_2SO_4 in a 125 ml erlenmeyer flask and filtered through pre-rinsed (hexanes) fine filter paper. The recovered fatty acids were converted to methyl esters with BF_3-MeOH (Morrison & Smith 1964), and one-third of the methyl esters was hydrogenated over platinum catalyst (Ackman et al 1967). In two cases, Ascophyllum nodosum and Fucus vesiculosus, 100 g lots of coarsely-chopped algae were blended with $CHCl_3$ (100 ml) and MeOH (50 ml) in a Sorvall Omni-mixer. The blades did not finely mince the algae as had been expected and the extraction was judged incomplete. The extracted total lipid was, however, recovered and saponified essentially as described above for whole algae. The fatty acids were recovered and converted to methyl esters. Gas-liquid chromatography used stainless-steel wall-coated columns, 46 m x 0.25 mm I.D., in a Perkin-Elmer 3920 apparatus with flame ionization detection. The liquid phases were SILAR-5CP (Applied Science Laboratories) and Apiezon-L. Respective operating temperatures were 170° and 180°C. The carrier gas was helium at a pressure of 3.5 $kgcm^{-2}$ (50 psig). The inlet-splitter system and manifold were operated at 225°C and output was recorded on a Honeywell 1 mV recorder fitted with a Disc Instruments Inc. ball and disc type integrator.

Peak areas were converted to weight percent through appropriate correction factors (Ackman et al 1967). Retention data and examples of chromatograms including 18:5ω3 will be found elsewhere (Ackman et al 1974; Mayzaud et al 1976).

RESULTS and DISCUSSION

The methanolic alkaline extraction of 10 g samples gave about the same yield of fatty acids (ca 0.02-0.05 g in most cases) as were recovered from the lipid extracted from the two 100 g samples with $CHCl_3$/MeOH. No obvious qualitative or quantitative difference in composition of

methyl esters was noted in the products from the two techniques and the alkali method is recommended as simpler and safer, and yielding ample ester for GLC study. The sole case of a poor yield from this procedure was of a Cladophora rupestris sample, but extraction of a second lot from the same sample gave the normal weight recovery of fatty acid. Pending further study the detailed fatty acid composition of this sample is omitted from this report.

Fatty acids found in most terrestrial plants extend from C_{14} to C_{18}, with a few families also including C_{20} and C_{22} acids, mostly monoethylenic. Aquatic plants (unicellular algae and seaweeds), especially marine species, afford a greater vareity of fatty acids than do most terrestrial plants (Hilditch & Williams 1964; Pohl & Wagner 1972; Wood 1974). All animals include polyethylenic fatty acids of the C_{20} and C_{22} chain lengths in their vital cellular membrane, and aquatic species also accumulate these in their depot fats (Ackman 1964; Hilditch & Williams 1964; Wagner & Pohl 1966). It is often convenient to classify plants and animals by the proportions of the three basic types of fatty acids, saturated, monoethylenic, and polyethylenic. Table II shows, however, that these totals are not especially different in the three divisions represented in the study.

The saturated fatty acids 14:0 and 16:0 are an interesting pair, as 16:0 is common and is the typical saturated fatty acid of terrestrial plants, whereas 14:0 is generally much less common (Hilditch & Williams 1964) except among certain families also containing 12:0 (lauric acid). As shown in Table II, 14:0 is relatively low in the two Chlorophyta listed (and in the unlisted C. rupestris), although Jamieson and Reid (1972b) reported appreciable 14:0 in C. rupestris (4.9%) and Cladophora albida (6.4%). Brush and Percival (1972) refer to 14:0 as "small" as galactolipids of Chlorophyta, and Hayashi et al (1974) give only 0.6% for Ulva pertusa, whereas Sato (1975) shows 3.6% for Codium fragile. The high proportion of 14:0 in the Phaeophyta, A. nodosum and F. vesiculosus, is confirmed by Jamieson and Reid (1972b), but the Rhodophyta, as well as some others of the Phaeophyta, also have moderately high levels of 14:0 except for Porphyra leucosticta. An apparent lack of saturated acid chain extensions (eg 14:0→16:0→18:0) in F. vesiculosus is also shown by the extremely low level of 18:0 (0.1%) compared to the percentages in the other algae. The exception (Table II) to the general importance of 14:0 is P. leucosticta, but a Porphyra sp studied by Sato et al (1974) had 14:0 at about 5% under some growth conditions but not others. Generalities are evidently difficult to sustain even with common fatty acids. Since odd-chain saturated acids are not reported in any other recent fatty acid study of North Atlantic seaweeds, except for 15:0 in some Chlorophyta examined by Jamieson and Reid (1972b), two are included in Table II. There is, however, no unusual proportion except in Agarum cribrosum (Laminarales). In this sample, 15:0 was accompanied by an equal amount of 15:1, presumably the Δ^9 (ie ω6) isomer, suggesting a basic involvement in the metabolism of 14:0 and/or 16:0. Since 18:0 was also high in A. cribrosum, it is not unexpected to find 17:0 and 17:1 (not shown) high in the same sample for similar reasons.

The monoethylenic acid 16:1ω7 (palmitoleic acid) is of special interest (Koroly & Corner 1976) because it may or may not be chain extended to 18:1ω7 (cis-vaccenic acid). The latter is not usually separated from 18:1ω9 (oleic acid) by packed-column gas-liquid chromatography. This separation is, however, readily achieved by open-tubular gas-liquid chromatography. Two examples, A. cribrosum (No. 13) and Acrosiphonia

Table II. Summary of fatty acid classes and of certain common saturated fatty acids in weight percent in 15 species of seaweeds

Fatty Acid	Acrosiphonia arcta	Blidingia minima
Σsaturated	35	21
Σmonoethylenic	13	20
Σpolyethylenic	59	59
14:0	1.2	0.5
16:0	33.4	20.0
18:0	0.2	0.1
15:0	0.2	0.1
17:0	0.2	<0.1

	Ralfsia fungiformis	Agarum cribrosum	Laminaria digitata	Alaria esculenta	Ascophyllum nodosum	Fucus vesiculosus
Σsaturated	24	34	25	18	27	27
Σmonoethylenic	26	27	23	11	25	10
Σpolyethylenic	50	39	52	71	48	63
14:0	1.9	5.4	5.4	5.5	12.4	21.5
16:0	19.9	23.7	19.8	12.4	15.0	5.5
18:0	0.5	1.2	0.7	0.7	0.3	<0.1
15:0	0.3	1.7	0.3	0.3	0.5	0.4
17:0	0.3	0.7	0.2	0.2	0.3	0.3

	Chondrus crispus	Gigartina stellata	Halosaccion ramentaceum	Palmaria palmata	Polysiphonia lanosa	Porphyra leucosticta	Ptilota serrata
Σsaturated	30	40	22	36	30	24	48
Σmonoethylenic	11	13	7	11	20	8	24
Σpolyethylenic	59	47	71	53	50	68	28
14:0	3.7	2.3	6.4	8.9	1.9	0.2	3.5
16:0	26.7	35.6	14.0	25.0	25.6	22.7	41.7
18:0	0.5	0.6	0.4	0.8	0.5	0.4	1.3
15:0	0.3	0.4	0.3	0.6	0.4	0.1	0.6
17:0	0.2	0.7	0.1	0.1	0.4	0.1	0.5

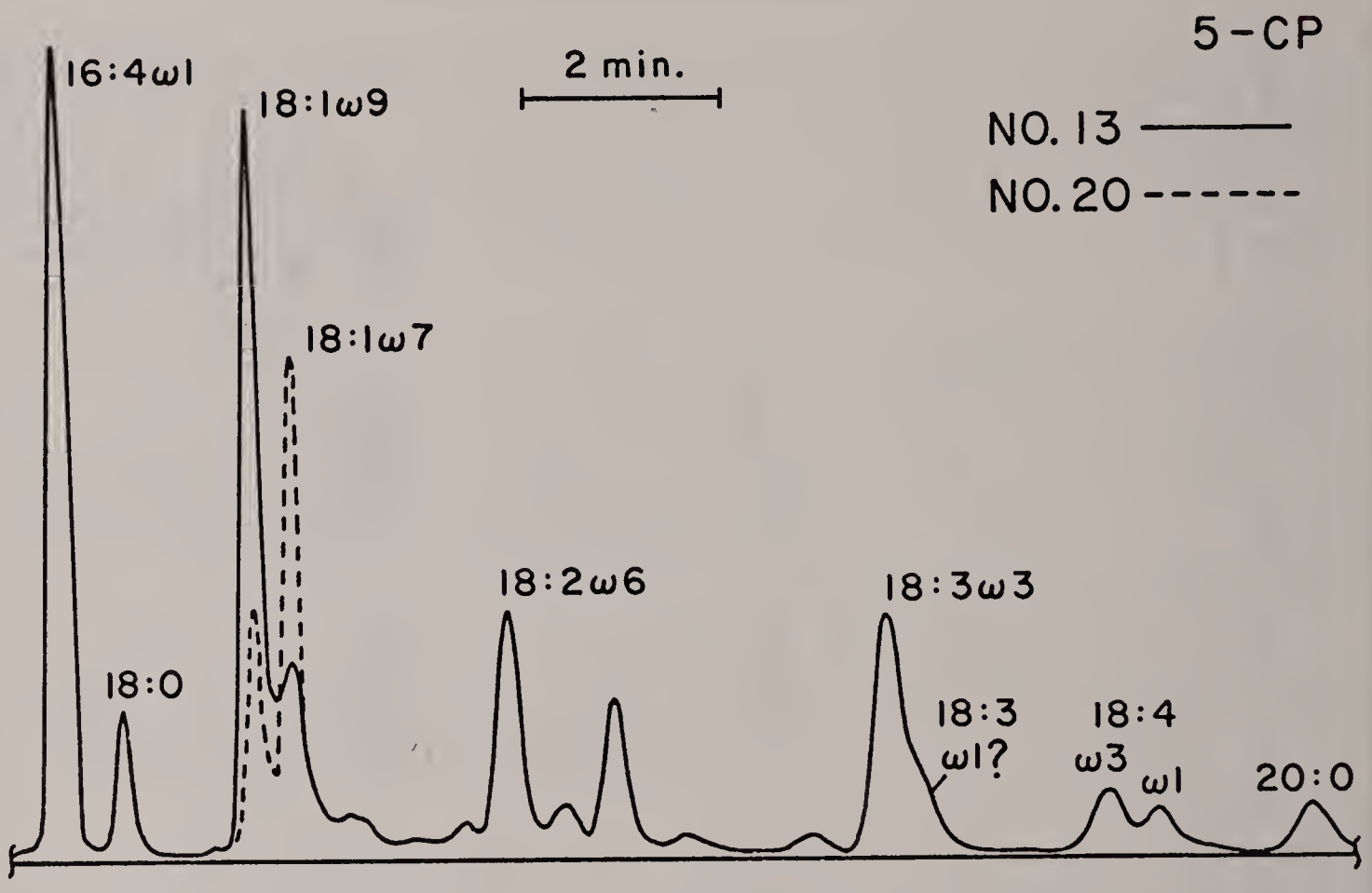

Fig 1. Part of the chart record from analysis by open-tubular gas-liquid chromatography on SILAR-5CP of the methyl esters of fatty acids from A. cribrosum (No. 13) compared with the 18:1 isomer sector of A. arcta (No. 20) to show differences in 18:1 isomer proportions. Note unknown shoulder following 18:3ω3 and small proportion of possible 18:4ω1. These are discussed in the text.

arcta (No. 20), are illustrated in Figure 1. In the one case there is a 6:1 ratio of ω9 to ω7, in the other the ratio is 0.6:1. The information provided by the separation of these two 18:1 isomers (Table III) is therefore novel. The dominance of 18:1ω7 over 18:1ω9 in the Chlorophyta is confirmed by the Cladophora data (not included) and separates this division from the Phaeophyta, although various Rhodophyta, especially Polysiphonia lanosa, also have high proportions of 18:1ω7 presumably derived from 16:1ω7. In view of possible contributions of macrophyte material to the local water column proposed by Mann (1972), these acids could be useful markers for biochemical processes, including local geochemistry (Volkman & Johns 1977) in the form of detritus fallout. Discussion of the longer chain (C_{20}, C_{22}) monoethylenic isomers is reserved for another report following further study. More than one isomer was observed in certain cases, but open-tubular gas-liquid chromatography can not separate certain isomers from each other (eg 22:1ω13 and 22:1ω11), although both can be separated from 22:1ω9 as shown by Ackman and Castell (1966).

The proportions among the C_{18} polyunsaturated acids (Table V) and C_{20} polyethylenic acids (Tables VI & VII) for Chondrus crispus, Gigartina stellata, Laminaria digitata, Alaria esculenta, A. nodosum, and F. vesiculosus are broadly in agreement with those reported by Jamieson and Reid (1972b). The absence (Table VII) of 22:5ω3 and 22:6ω3 in A. nodosum and F. vesiculosus (Fucales) differs from Jamieson and Reid's report (1972) of as much as 1.9% of 22:5ω3 in F. vesiculosis. Such chain extension in this class of macrophyte is not improbable as we noted 5.2%

Table III. Important and unusual isomers of C_{14}, C_{16}, and C_{18} monoethylenic fatty acids in weight percent

Isomers	Acrosiphonia arcta	Blidingia minima
16:1ω7	7.2	3.3
18:1ω9	1.3	0.1
18:1ω7	2.3	14.0
Trans 14:1ω11	<0.1	0.0
Trans 16:1ω13	0.8	2.5

	Ralfsia fungiformis	Agarum cribrosum	Laminaria digitata	Alaria esculenta	Ascophyllum nodosum	Fucus vesiculosus
16:1ω7	1.6	13.0	2.9	0.5	2.1	1.1
18:1ω9	22.1	5.9	18.9	6.9	15.9	6.9
18:1ω7	0.7	0.9	0.2	0.3	0.7	0.1
Trans 14:1ω11	0.3	0.8	0.2	0.5	0.0	0.0
Trans 16:1ω13	0.7	0.1	0.6	1.9	0.2	0.3

	Chondrus crispus	Gigartina stellata	Halosaccion ramentaceum	Palmaria palmata	Polysiphonia lanosa	Porphyra leucosticta	Ptilota serrata
16:1ω7	0.5	3.2	0.2	0.6	8.2	0.4	7.7
18:1ω9	6.2	6.0	3.0	3.6	1.7	2.0	9.4
18:1ω7	1.5	2.6	0.8	1.5	8.2	1.0	5.1
Trans 14:1ω11	0.1	0.0	0.1	0.1	0.0	<0.1	0.1
Trans 16:1ω13	0.9	0.4	1.8	1.8	0.9	1.9	0.1

Table IV. Isomers of C_{20} and C_{22}, and total 24:1 monoethylenic fatty acids, in weight percent

Isomers	Acrosiphonia arcta	Blidingia minima
20:1ω11	<0.1	0.0
20:1ω9	1.1	0.0
20:1ω7	<0.1	<0.1
22:1ω13 + 11	0.0	0.0
22:1ω9	0.3	0.0
22:1ω7	0.0	<0.1
24:1	<0.1	0.0

	Ralfsia fungiformis	Agarum cribrosum	Laminaria digitata	Alaria esculenta	Ascophyllum nodosum	Fucus vesiculosus
20:1ω11	0.1	0.1	<0.1	0.1	0.2	0.1
20:1ω9	0.1	<0.1	<0.1	0.1	0.1	0.0
20:1ω7	0.1	<0.1	<0.1	0.2	<0.1	<0.1
22:1ω13 + 11	0.0	<0.1	0.0	0.0	0.2	0.1
22:1ω9	0.0	<0.1	0.0	0.0	0.0	0.0
22:1ω7	0.0	0.0	0.0	0.0	0.0	0.0
24:1	0.0	0.0	0.0	0.0	0.4	0.1

	Chondrus crispus	Gigartina stellata	Halosaccion ramentaceum	Palmaria palmata	Polysiphonia lanosa	Porphyra leucosticta	Ptilota serrata
20:1ω11	<0.1	0.0	0.0	<0.1	<0.1	0.0	0.2
20:1ω9	<0.1	0.2	0.5	1.2	0.1	2.3	0.1
20:1ω7	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.0
22:1ω13 + 11	0.0	0.0	<0.1	0.1	0.1	<0.1	<0.1
22:1ω9	0.0	0.2	0.2	0.8	<0.1	<0.1	0.1
22:1ω7	0.0	0.0	<0.1	0.0	0.0	0.0	0.0
24:1	0.0	<0.1	<0.1	0.0	0.0	0.0	0.2

Table V. Common isomers of C_{18} polyethylenic fatty acids in weight percent

Isomers	Acrosiphonia arcta	Blidingia minima
18:2ω6	4.0	3.0
18:3ω6	0.5	0.4
18:3ω3	17.4	17.0
18:4ω3	11.4	15.7

	Ralfsia fungiformis	Agarum cribrosum	Laminaria digitata	Alaria esculenta	Ascophyllum nodosum	Fucus vesiculosus
18:2ω6	9.2	2.2	8.5	4.6	6.0	9.4
18:3ω6	1.0	0.2	0.5	0.6	0.2	0.7
18:3ω3	5.0	3.7*	6.3	10.6	5.1	10.4
18:4ω3	7.2	1.2**	9.7	24.6	6.2	13.5

	Chondrus crispus	Gigartina stellata	Halosaccion ramentaceum	Palmaria palmata	Polysiphonia lanosa	Porphyra leucosticta	Ptilota serrata
18:2ω6	2.4	1.1	0.6	0.6	2.2	1.4	1.2
18:3ω6	0.9	0.4	0.2	0.2	0.7	0.5	0.2
18:3ω3	1.9	3.1	1.0	0.9	1.0*	0.1	0.2*
18:4ω3	3.5	0.7	2.6	1.8	2.1	0.2	0.3

* Possible 18:3ω1 may accompany 18:3ω3 in A. cribrosum and P. lanosa; same or different component found in P. serrata.

** Accompanied by 0.8% tentatively identified 18:4ω1.

Table VI. Selected polyethylenic C_{20} and C_{22} fatty acids of the ω6 family in weight percent

Fatty Acid	Acrosiphonia arcta	Blidingia minima
20:2ω6	0.1	<0.1
20:3ω6	0.0	0.1
20:4ω6	0.1	0.2
22:4ω6	0.0	0.3

	Ralfsia fungiformis	Agarum cribrosum	Laminaria digitata	Alaria esculenta	Ascophyllum nodosum	Fucus vesiculosus
20:2ω6	0.2	0.1	0.1	0.1	1.8	0.2
20:3ω6	1.3	0.1	0.4	0.4	0.3	0.7
20:4ω6	9.7	7.2	11.4	13.6	13.3	12.6
22:4ω6	<0.1	0.5	0.0	<0.1	0.1	0.1

	Chondrus crispus	Gigartina stellata	Halosaccion ramentaceum	Palmaria palmata	Polysiphonia lanosa	Porphyra leucosticta	Ptilota serrata
20:2ω6	0.1	0.1	<0.1	0.1	0.2	1.1	0.3
20:3ω6	0.4	0.2	<0.1	0.1	0.5	2.2	<0.1
20:4ω6	23.9	14.3	0.9	0.9	3.1	6.3	3.0
22:4ω6	0.0	0.2	<0.1	0.1	0.0	0.0	<0.1

Table VII. Selected polyethylenic C_{20} and C_{22} fatty acids including the ω3 family in weight percent

Fatty Acid	Acrosiphonia arcta	Blidingia minima
20:3ω3	0.1	0.1
20:4ω3	0.7	0.3
20:5ω3	2.3	0.6
22:5ω3	0.6	0.7
22:6ω3	1.9	0.0

	Ralfsia fungiformis	Agarum cribrosum	Laminaria digitata	Alaria esculenta	Ascophyllum nodosum	Fucus vesiculosus
20:3ω3	0.1	0.1	<0.1	<0.1	0.4	0.1
20:4ω3	0.1	0.1	0.4	0.5	0.1	0.8
20:5ω3	14.3	4.6	13.9	15.7	9.7	14.3
22:5ω3	0.1	5.2	0.0	0.0	0.0	0.0
22:6ω3	0.1	0.0	0.0	0.0	0.0	0.0
Δ^5,11 20:2	0.0	<0.1	<0.1	<0.1	0.1	<0.1
Δ^5,11,14 20:3	<0.1	<0.1	<0.1	0.1	2.1	0.1
Δ^5,11,14,17 20:4	0.1	0.1	0.1	0.1	1.8	0.1

	Chondrus crispus	Gigartina stellata	Halosaccion ramentaceum	Palmaria palmata	Polysiphonia lanosa	Porphyra leucosticta	Ptilota serrata
20:3ω3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3
20:4ω3	0.1	0.1	0.1	0.1	0.1	0.2	<0.1
20:5ω3	24.9	24.3	63.7	45.5	36.4	56.0	21.6
22:5ω3	0.0	0.2	<0.1	0.0	0.0	0.1	0.0
22:6ω3	0.0	0.0	<0.1	0.0	0.0	0.0	0.0
Δ^5,11 20:2	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0
Δ^5,11,14 20:3	0.1	0.0	0.0	0.1	<0.1	0.0	0.0
Δ^5,11,14,17 20:4	<0.1	0.0	0.0	0.2	0.1	<0.1	0.1

Table VIII. Selected tentatively identified polyethylenic C_{16} fatty acids, and totals of other similar acids, in weight percent

Fatty Acid	Acrosiphonia arcta	Blidingia minima
16:2ω6	1.0	0.6
16:3ω6	<0.1	<0.1
16:3ω3	3.0	1.8
16:4ω3	7.7	16.4
16:2ω7	0.0	0.1
16:2ω4	0.2	0.9
16:4ω1	0.2	0.1
Other*	0.0	0.3

	Ralfsia fungiformis	Agarum cribrosum	Laminaria digitata	Alaria esculenta	Ascophyllum nodosum	Fucus vesiculosus
16:2ω6	<0.1	0.0	<0.1	0.0	0.0	<0.1
16:3ω6	<0.1	0.3	<0.1	0.0	0.0	0.0
16:3ω3	<0.1	<0.1	<0.1	0.1	0.1	0.1
16:4ω3	0.1	0.0	<0.1	<0.1	<0.1	0.2
16:2ω7	<0.1	0.6	<0.1	0.1	0.0	<0.1
16:2ω4	0.0	3.3	0.0	0.0	0.0	0.0
16:4ω1	0.1	6.6	0.1	0.1	<0.1	0.1
Other*	<0.1	1.1	<0.1	0.1	0.0	<0.1

	Chondrus crispus	Gigartina stellata	Halosaccion ramentaceum	Palmaria palmata	Polysiphonia lanosa	Porphyra leucosticta	Ptilota serrata
16:2ω6	<0.1	<0.1	0.0	0.1	<0.1	0.0	0.0
16:3ω6	<0.1	0.0	<0.1	0.1	<0.1	<0.1	<0.1
16:3ω3	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1
16:4ω3	<0.1	1.1	<0.1	<0.1	<0.1	<0.1	<0.1
16:2ω7	0.0	<0.1	0.1	0.0	<0.1	<0.1	<0.0
16:2ω4	0.7	0.2	0.1	<0.1	2.9	0.0	0.0
16:4ω1	0.1	0.1	0.1	0.0	0.2	0.0	0.1
Other*	0.0	<0.1	2.1	2.9	<0.1	<0.1	0.0

* Mostly component of ECL (SILAR-5CP) of 16.63 important at 2.1% in H. ramentaceum and 2.9% in P. palmata, and possible 16:3ω1 in A. cribrosum.

of 22:5ω3 in A. cribrosum and traces (ca 0.1%) of 22:5ω3 and 22:6ω3 in Ralfsia fungiformis. Our work confirms the report of Jamieson and Reid (1972b) that A. nodosum, but not F. vesiculosus, is relatively rich in the unusual series of polyethylenic acids with isolated Δ^5 unsaturation. These occur in different forms in various terrestrial plant families (Fedeli & Tacini 1971; Jamieson & Reid 1972a; Pohl & Wagner 1972), as well as sponges (Morales & Litchfield 1976), shellfish, and other marine forms (Paradis & Ackman 1977). Traces of these acids also were found in the other Phaeophyta, and in the Rhodophyta, except for G. stellata and Halosaccion ramentaceum.

The emphasis on the "ω6" acids in algae (Table VI), especially 20:4ω6 (Nichols & Appleby 1969), is always a novelty to lipid chemists as this series of fatty acids, essential to terrestrial animals (Crawford et al 1976), is replaced by the "ω3" acids in most lipids of marine fish, and to some extent in freshwater fish (Ackman 1967).

The C_{16} polyethylenic fatty acids present an unusual analytical problem, owing to the possible coincidences with iso and anteiso 17:0, 17:1 etc. They also may include a peculiar series with "ω" values of 1, 4 and 7, found when 16:0 is subject to the desaturation processes intended to produce the polyethylenic C_{18} acids from 18:0. These C_{16} polyunsaturated acids are common in certain phytoplankters (Ackman 1964). In Table VIII are presented data based on tentative identifications of some of the important polyunsaturated C_{16} acids and a total for others assumed to be acids of this chain length. One with an ECL (equivalent chain length) of 17.00 on SILAR-5CP, probably 16:2ω4, was important in P. lanosa at 2.9%, in A. cribrosum at 3.3%, in Blidingia minima at 0.9% in C. crispus at 0.7% and in G. stellata and A. arcta at 0.2% each. In close proximity, at ECL 16.79 in SILAR-5CP, is the component listed in Table VIII as 16:2ω6. The A. cribrosum sample was also remarkable for the high proportion of the component tentatively identified throughout the study as 16:4ω1. (ECL 17.83 on SILAR-5CP and an ECL of 15.40 on AP-L). It is probably significant that this sample had the lowest level among the Phaeophyta (Table V) of the 18:4ω3 related as described by Ackman (1964), but this was accompanied by a relatively important component (Fig 1,2) thought to be 18:4ω1. The tentatively identified 16:4ω3 (ECL 17.63 on SILAR-5CP and 15.35 on AP-L) amounted to 1.1% in G. stellata, but otherwise was important only in the two samples of Chlorophyta. A C. rupestris sample (data not presented) included the component presumed to be 16:4ω3 at a moderately high proportion of unsaturation. Jamieson and Reid (1972b) list 16:4ω3 at 10 to 20% in three Chlorophyta and 7.2% in another. Our levels of 16:3ω3 for Chlorophyta are also similar to theirs at 2 to 3%. These authors have discussed the discrepancies between their work and earlier studies for fatty acids of all chain lengths. It is suspected that trace percentages of 16:4ω3 and 16:4ω1 could in some cases be 17:2 isomers.

One other interesting but unidentified component in various samples disappeared on hydrogenation and was therefore unsaturated and probably C_{16}. It had an ECL of 16.63 on SILAR-5CP and an ECL of 15.95 on AP-L. This was important only in Palmaria palmata at 2.9% (Table VIII), and in H. ramentaceum at 2.0%. Evidently further work detailing the structures of the expected C_{16} polyunsaturated acids and observed peaks in GLC is required, especially on newer type GLC phases of the cyanoalkyl types such as SILAR-5CP. There were various other unusual fatty acids noted in this study. In addition to the trans-3-hexadecenoic

(trans-16:1ω13) acid already reported for common North Atlantic algae at approximately the 1% level by Jamieson and Reid (1972b), the corresponding trans-3-tetradecenoic and some trans-2-hexadecenoic acids were suspected as trace components in some samples (Table III). There were also several occurrences of unsaturated materials giving iso-15:0 on hydrogenation, and known to be monoethylenic from their retention times on the two liquid phases studied. Such acids are more often associated with bacteria (Boon et al 1977; Weeks 1976) than plants and may not be actual algal fatty acids.

Despite the high proportion of 20:5ω3 in several species, especially in the Rhodophyta (see below) no significant amount (ie 0.1% or more) of 18:5ω3 could be found in any of the macrophytes examined. A trace component, possibly 18:5ω3, at (0.02%) in P. leucosticta was quantitatively the most likely candidate. Each mixture of methyl esters was examined critically for this component on the polar liquid phase SILAR-5CP and the non-polar Apiezon-L. To confirm 18:5ω3, matching component peaks would have to be found in analyses on both polar and non-polar columns. Often a number of components on Apiezon-L (ed Fig 2) quantitatively matched one or more components on SILAR-5CP (Fig 1) and confused the issue. The 18:5ω3 position on SILAR-5CP at approximately ECL 20.13 is not presented in Figure 1 as the attenuation employed did not show any component of the relative size of "A" of Figure 2.

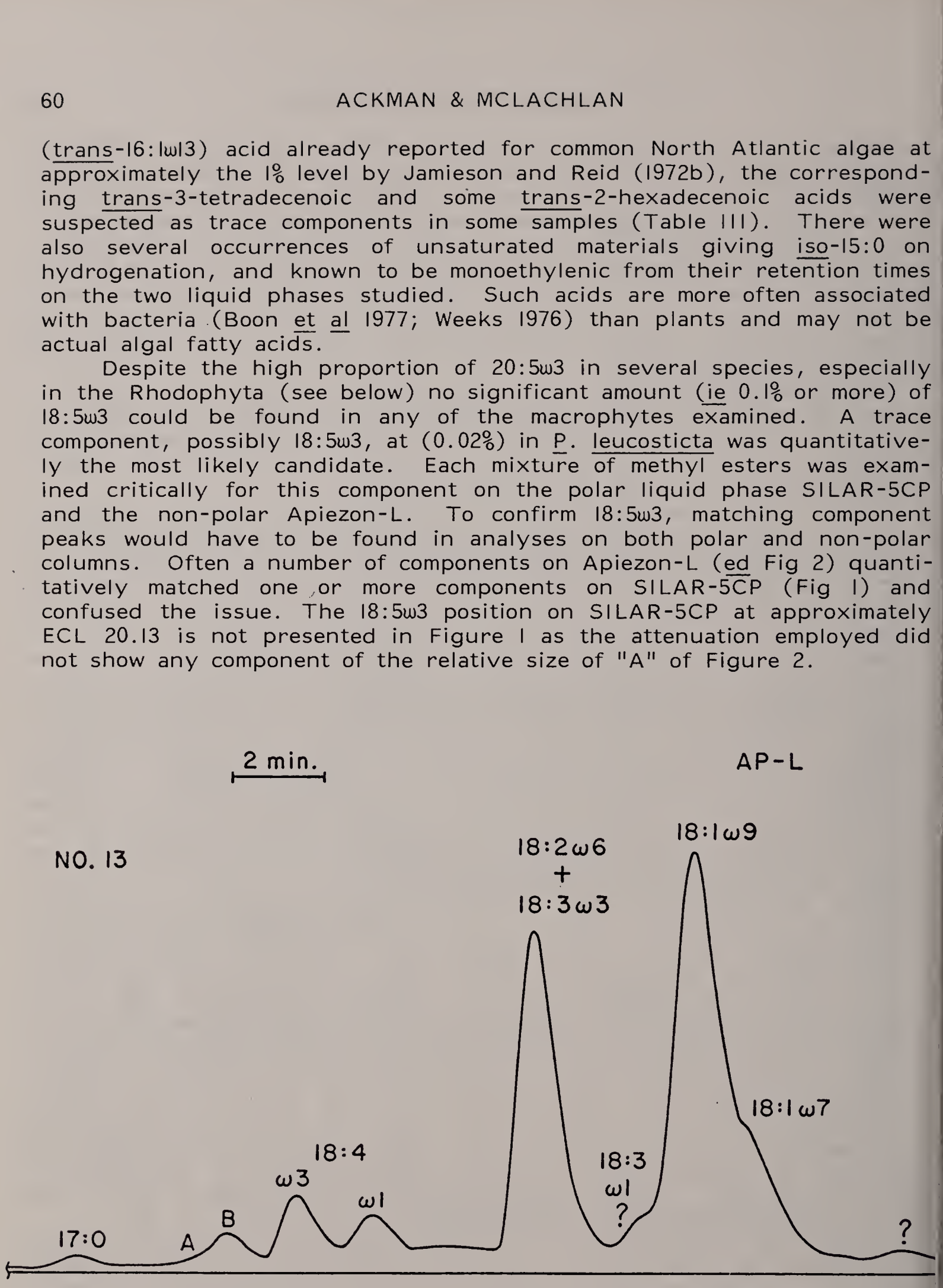

Fig 2. Part of the chart record from analysis by open-tubular gas-liquid chromatography on Apiezon-L of the methyl esters of fatty acids from A. cribrosum. Note two isomers of 18:4, shoulder for possible 18:3ω1, and minor component B. (See Fig 1 and text discussion).

The open-tubular gas-liquid chromatographic analyses resolve some questions and create others. In the analysis of A. cribrosum on the polar phase SILAR-5CP (Fig 1) a shoulder was observed following the 18:3ω3 peak. Another laboratory independently observed the same effect (M. Ikawa, in litt). Speculative calculations (Ackman & Hooper 1973a; 1973b; Ackman et al 1974) of retention time for various C_{18} polyunsaturated fatty acids indicate that 18:4ω6 would have an ECL value on SILAR-5CP of between 19.45 and 19.61 (estimated ECL for shoulder component is 19.50). On AP-L 18:4ω6 can be more closely calculated to have an ECL value of about 17.17, and a component "B" of the correct size is located in this position at ECL 17.18 (Fig 2). Alternatively, instead of a chain shortening product (20:4ω6→18:4ω6), chain elongation of 16:3ω1 would be more probable (compare 16:4ω1→18:4ω1), and lead to a possible 18:3ω1 (the shoulder so marked in Fig 2). Different proportions of a component following or trailing 18:3ω3 (SILAR-5CP analyses) also were seen in the mutually related (Ceramiales) P. serrata and P. lanosa of the Rhodophyceae. These appear to lack the 16:3ω1 precursor for 18:3ω1, and are not especially rich in 20:4ω6. These algae may contain yet another unusual C_{18} fatty acid requiring further study.

It must be concluded that the chance of finding quantities of 3,6,9, 12,15-octadecapentanoic acid in macrophytes appears slim although several of the samples studied had high proportions of the related 20:5ω3. However, there is a wealth of detail in the fatty acids of Nova Scotian seaweeds which can be conveniently revealed by open-tubular gas-liquid chromatography for more detailed study. The levels of fatty acids in seaweeds are low (Hayashi et al 1974; Wagner & Pohl 1965) but when compared to the limited yields from cultures of unicellular algae (Ackman et al 1968; Collyer 1962; Ivanova & Popov 1972; Stoianova & Mladenova 1972) seaweeds offer immediate large-scale sources for recovery of specific fatty acids, for example the extremely pure 16:1ω7 (palmitoleic acid) of G. stellata or the virtually pure 18:1ω7 (cis-vaccenic acid) of B. minima.

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REFERENCES

ACKMAN, R.G. 1964. Structural homogeneity in unsaturated fatty acids of marine lipids: A review. J. Fish. Res. Bd. Canada, 21:247-54.

ACKMAN, R.G. 1967. Characteristics of the fatty acid composition and biochemistry of some fresh-water fish oils and lipids in comparison with marine oils and lipids. Comp. Biochem. Physiol. 22:907-22.

ACKMAN, R.G. and Castell, J.D. 1966. Isomeric monoethylenic fatty acids in herring oil. Lipids, 1:341-48.

ACKMAN, R.G. and Hooper, S.N. 1963. Additivity of retention data for ethylenic functions in aliphatic fatty acids. I. Apiezon-L. J. Chromatog. 86:73-81.

ACKMAN, R.G. and Hooper, S.N. 1973. Additivity of retention data for ethylenic functions in aliphatic fatty acids. II. Polar liquid phases. J. Chromatog. 86:83-88.

ACKMAN, R.G. and McLachlan, J. 1978. Octadecapentaenoic acid and macrophytes. Proc. Int. Seaweed Symp. 9:(in press).

ACKMAN, R.G., and Manzer, A., and Joseph, J. 1974. Tentative identification of an unusual naturally-occurring polyenoic fatty acid by calculations from precision open-tubular GLC and structural element retention data. Chromatographia, 7:107-14.

ACKMAN, R.G., Sipos, J.C., and Jangaard, P.M. A quantitation problem in the open tubular gas chromatography of fatty acid esters from cod liver lipids. Lipids, 2:251-57.

ACKMAN, R.G., Tocher, C.S., and McLachlan, J. 1968. Marine phytoplankter fatty acids. J. Fish. Res. Bd. Canada, 25:1603-08.

BOON, J.J., de Leeuw, J.W., v.d. Hoek, C.J., and Vosjan, J.-H. 1977. Significance and taxonomic value of iso and anteiso monoenoic fatty acids and branched β-hydroxy acids in Desulfovibrio desulfuricans. J. Bacteriol. 129:1183-91.

BRUSH, P. and Percival, E. 1972. Chlorophyta: Chlorophyceae; glycolipids present in eight genera of the chlorophyceae. Phytochemistry, 11:1847-49.

CHUECAS, L. and Riley, J.P., 1966. The component fatty acids of some sea-weed fats. J. Mar. Biol. Ass. U. K. 46:153-159.

COLLYER, D.M. 1962. Method for determination of fat percentage in unicellular algae. J. Mar. Biol. Ass. U. K. 42:485-92.

CRAWFORD, M.A., Casperd, N.M., and Sinclair, A.J.. The long chain metabolites of linoleic and linolenic acids in liver and brain in herbivores and carnivores. Comp. Biochem. Physiol. 54B:395-01.

FEDELI, E. and Tacini, G. 1971. Lipid composition of vegetable oils. In: Advances in Lipid Research. (eds. Paoletti, R. and D. Kritchevsky). Vol 9, pp. 335-82. Academic Press, New York.

HAYASHI, K., Kida, S., Kato, K., and Yamada, M. 1974. Component fatty acids of acetone-soluble lipids of 17 species of marine benthic algae. Bull. Jap. Soc. Sci. Fish. 40:609-17.

HILDITCH, T.P. and Williams, P.M. 1976. The Chemical Composition of Natural Fats, 4th Edition, Chapman and Hall, London.

IVANOVA, B. and Popov, A. 1972. Method of quantitative extraction of lipids from green algae. Prikl. Biokhim. Mikrobiol. 8:99-106.

JAMIESON, G.R. and Reid, E.H. 1972a. The leaf lipids of some conifer species. Phytochemistry, 11:269-75.

JAMIESON, G.R. and Reid, E.G. 1972b. The component fatty acids of some marine algal lipids. Phytochemistry, 11:1423-32.

JOSEPH, J.D. 1975. Identification of 3,6,9,12,15-octadecapentaenoic acid in laboratory-cultured photosynthetic dinoflagellates. Lipids, 10:395-403.

KLENK, K., Knipprath, W., Eberhagen, D., and Koof, H.P. 1963. On the unsaturated fatty acids of lipids of freshwater and marine algae. Hoppe-Seyler's Z. Physiol. Chemie, 334:44-59.

KOROLY, M.J. and Corner, R.L. 1976. Unsaturated fatty acid biosynthesis in Tetrahymena: Evidence for two pathways. J. Biol. Chem. 10:7588-92.

LAUR, M.-H. 1965. 1re These: Les Lipides de Quelques Rhodophycees (Recherches Cytochimiques, Chimiques et Physiologiques). Univ. Paris, 93 p.

MANN, K.H. 1972. Ecological energetics of the sea-weed zone in a marine bay on the Atlantic coast of Canada. II. Productivity of the seaweeds. Mar. Biol. 14: 199-209.

MAYZAUD, P., Eaton, C.A., and Ackman, R.G. 1976. The occurrence and distribution of octadecapentaenoic acid in a natural plankton population. A possible food chain index. Lipids, 11:858-62.

MORRISON, W.R. and Smith, L.M. 1964. Preparation of fatty acid methyl esters and dimethyl acetals from lipids with boronfluoride-methanol. J. Lipid Res. 5:600-08.

MORALES, R.W. and Litchfield, C. 1976. Unusual C_{24}, C_{25}, C_{26} and C_{27} polyunsaturated fatty acids of the marine sponge Microciona prolifera. Biochim. Biophys. Acta, 431:206-16.

NEISH, A.C., Shacklock, P.F., Fox, C.H., and Simpson, F.J. 1977. The cultivation of Chondrus crispus. Factors affecting growth under greenhouse conditions. Can. J. Bot. 55:2263-71.

NICHOLS, B.W. and Appleby, R.S. 1969. The distribution and biosynthesis of arachidonic acid in algae. Phytochemistry, 8:1907-15.

NICHOLS, B.W., Harris, P., and James, A.T. 1965. The biosynthesis of trans-Δ^3-hexadecenoic acid by Chlorella vulgaris. Biochem. Biophys. Res. Comm. 21:473-79.

PARADIS, M. and Ackman, R.G. 1977. Potential for employing the distribution of anomalous non-methylene-interrupted dienoic fatty acids in several marine invertebrates as part of food web studies. Lipids, 12:170-76.

POHL, P. and Wagner, H. 1972. Fatty acids in plants and animals (a review). I: Saturated and cis-unsaturated fatty acids. Fette Seifen Anstrichmittel, 74:424-35.

SATO, S. 1975. Fatty acid composition of lipids in some species of marine algae. Bull. Jap. Soc. Sci. Fish. 41:1117-1183.

SATO, S., Kayama, M., and Mashiba, M. 1974. Effects of environmental factors on the lipid components of Porphyra sp. J. Fac. Fish. Anim. Husb., Hiroshima Univ. 13:199-05.

STOIANOVA-IVANOVA, B. and Mladenova, K. 1972. On the composition of lipids in the brown alga (Cystoseira barbata). C. R. Acad. Bulg. Sci. 25:767-70.

VOLKMAN, J.K. and Johns, R.B. 1977. The geochemical significance of positional isomers of unsaturated acids from an intertidal zone sediment. Nature, 267:693-94.

WAGNER, H. and Pohl, P. 1965. Micro analysis of unsaturated fatty acids from marine algae (green, red and brown). Biochemische Z. 341:476-84.

WAGNER, H. and Pohl, P. 1966. Fatty acid biosynthesis and evolution in plant and animal organisms. Phytochemistry, 5:903-20.

WEEKS, G. 1976. The manipulation of the fatty acid composition of Dictostelium discoideum and its effect on cell differentiation. Biochim. Biophys. Acta, 450:21-32.

WOOD, B.J.B. 1974. Fatty acids and saponifiable lipids. Bot. Monogr. 10:236-65.

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INVESTIGATIONS OF THE MARINE ALGAE OF NOVA SCOTIA: XIII. CYANOPHYCEAE*

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Fifty-six taxa of cyanophycean algae, including species now recognized as ecophenes under recent taxonomic revisions, are reported as new to the marine algal flora of Nova Scotia; 43 of these are also first records for the Maritime Provinces. Each taxon is illustrated, and brief accounts of habitat and seasonality are given.

Although the marine algal flora of Nova Scotia is well documented in various published records of Chlorophyceae, Phaeophyceae, and Rhodophyceae (eg, Bell & MacFarlane 1933; Edelstein et al 1967; Edelstein & McLachlan 1967a, b; MacFarlane & Milligan 1966), the Cyanophyceae have thus far received only sporadic mention or have been omitted altogether from both provincial surveys and more general regional reviews (South 1976; Taylor 1957). This neglect has stemmed partly from difficulties in identifying an abundance of closely similar taxa, and partly from uncertain taxonomy following recent drastic revisions (Drouet 1968, 1973; Drouet & Daily 1956). Two reports (Hughes 1949; Smith 1938), however, list cyanophycean algae from freshwater habitats in Nova Scotia, and blue-green algae are well represented in one marine and several freshwater studies from other points in the Maritime Provinces (Habeeb & Drouet 1948; Klugh 1917, 1921, 1927; Smith 1946, 1952; Staker 1976). As this group of algae is a widespread and sometimes conspicuous component of our coastal flora, we now extend our knowledge of Nova Scotian algae by reporting on the marine Cyanophyceae.

MATERIAL, NOMENCLATURE and INCLUDED TAXA

Specimens examined were incidental collections of blue-green algae made during the past 12 yr and stored in the marine algal herbarium of the Atlantic Regional Laboratory. Additionally, many records are based on intensive sampling in salt-marsh habitats since 1972, although herbarium specimens were always not secured from these collections. Whenever possible, collections were inspected in the living state, and samples were often maintained in refrigerated, crude seawater culture for this purpose.

Nomenclature follows the revisions of Drouet and Daily (1956) for coccoid taxa, of Drouet (1968) for the Oscillatoriaceae, and of Drouet (1973) for cylindrical Nostocaceae. As these concepts of cyanophycean taxonomy have not been universally accepted, we retain the traditional

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nomenclature within these groups to the extent of recognizing 'classical species' separately as ecophenes or environmental variants; this is for comparison with earlier reports of cyanophytes from the Maritime Provinces and other literature using the older taxonomy. For these ecophenes and for catenate Nostocaceae and the Nostochopsidaceae (Stigonematales), nomenclature is used as determined from various sources, notably Geitler (1932). Wherever possible, author citations are adopted from Parke and Dixon (1968, 1976).

Only those taxa which occurred in sufficient quantity to allow identification with reasonable certainty are included. Tentative determinations of isolated cells or filaments are thus omitted because of probable misrepresentation of such classical diagnostic criteria as growth habit and nature of sheath. Also, a number of small taxa is subject to confusion with certain bacteria, and is excluded pending further opportunity to study them in the living state.

Most taxa listed herein represent new records from marine habitats in Nova Scotia; however, some species or ecophenes have been reported previously from freshwater, as indicated in the text. Several previously recorded and relatively abundant taxa in marine habitats are discussed briefly for purposes of comparison. Four recorded species are excluded because further observations are meagre or lacking; these are: Anabaena cylindrica Lemm. (McLachlan & Edelstein 1970-71); Anacystis marina (Hansg.) Dr. & D. (McLachlan & Edelstein 1970-71, as Aphanocapsa marina Hansg. ex Fosl.); A. montana (Lightf.) Dr. & D. f. montana [Stephenson & Stephenson 1954, as Gloeocapsa alpicola (Lyngb.) Born.]; and Nostoc microscopicum Born. & Flah. (Stephenson & Stephenson 1954). Altogether, 31 species are discussed, comprising 56 ecophenes or 'classical species' reported as new to the marine algal flora of Nova Scotia, and 43 as new to the Maritime Provinces.

CHROOCOCCALES

Chroococcaceae

Agmenellum quadruplicatum (Bréb.) Menegh.

Ecophene: Merismopedia punctata Meyen (Fig 1,2)

In salt marsh pans, or mixed with benthic cyanophytes in swards of Spartina patens (Ait.) Muhl.; Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; Kingsport, Kings Co.; uncommon, July, August.

Previous records in Nova Scotia: Hughes (1949), as Merismopedia glauca (Ehr.) Näg., M. punctata; Smith (1938), as M. glauca; all in freshwater.

Merismopedia punctata is ordinarily a freshwater ecophene, although Geitler (1932) cites a marine record. Typical salinity of one salt marsh pan in which this entity occurred is 25°/$_{oo}$.

*Agmenellum thermale (Kütz.) Dr. & Daily

Ecophenes: Merismopedia convoluta Bréb. in Kütz. (Fig 66)
M. glauca (sensu Frëmy 1929-33; Geitler 1932) (Fig 3)

Salt marshes; in detritus of pans or mixed with filamentous Chlorophyceae and other blue-green algae in floating mats or benthic turfs;

*New record for Maritime Provinces.

Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; rare to common, June-August.

Merismopedia convoluta is a freshwater ecophene according to Desikachary (1959) and Geitler (1932), but is recorded from salt marshes by Frémy (1929-33). The present specimens were found in a low-level pan with salinity about 25°/$_{oo}$.

Merismopedia glauca is included in Agmenellum quadruplicatum (Drouet & Daily 1956). However, the range of cell diameter given for M. glauca by several authors (Frémy 1929-33; Geitler 1932; Prescott 1951) is comparable with that of A. thermale which characteristically has larger cells than A. quadruplicatum. The ecophene designated herein as M. glauca is a small colony with relatively distant cells 5-5.5 µm wide, corresponding well with various descriptions in the literature. It is thus possible that prior records of M. glauca in Nova Scotia (Hughes 1949; Smith 1938) may have been similar, large-celled forms also assignable to A. thermale.

Anacystis dimidiata (Kütz.) Dr. & D.

Ecophene: Chroococcus turgidus (Kütz.) Näg. (Fig 4, 5)

Salt marshes: in pans or algal turf in swards of Spartina Schreb. and Juncus L.; Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; Kingsport, Kings Co.; rare to occasional, June-September.

Previous record in Nova Scotia: Smith (1938), as C. turgidus, in freshwater.

Coccochloris stagnina Spreng.

Ecophenes: Aphanothece stagnina Braun in Rabenh. (Fig 6)
*Chroococcus minutus (Kütz.) Näg. (Fig 7, 8)
*Microcystis litoralis (Hansg. in Fosl.) Forti in de Toni (Fig 9)
M. pallida (Kütz.) Lemm. (Fig 10)

On Zostera L., Fucus L., Polysiphonia Grev., Rhizoclonium Kütz., and with other cyanophytes in salt-marsh habitats, at times floating in pans: Crystal Cliffs, Point Town, and Pomquet Harbour, Antigonish Co.; Kingsport, Kings Co.; widespread, occasionally locally dominant, June-October, December.

Previous record in Nova Scotia: Hughes (1949), as A. stagnina, in freshwater.

The most common ecophenes of this species were A. stagnina and M. pallida, with observed maximum development as crowded flocculent colonies in and at the surface of marsh pans.

Gomphosphaeria aponina Kütz.

Ecophene: G. aponina (sensu stricto) (Fig 11)

Among detritus in salt-marsh pans and wet depressions, or associated with filamentous green algae beneath Spartina alterniflora; Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; Waugh Island, Cumberland Co.; colonies were usually numerous when present, June-August, October, December.

*Johannesbaptistia pellucida (Dickie) W. R. Taylor & Dr.

Ecophene: Cyanothrix willei Gardn. (Fig 12)

Among detritus in a salt-marsh pan; Pomquet Harbour, Antigonish Co.; rare, July.

The width of protoplasts in the Nova Scotian specimens, at 3.5-4.5 µm, is smaller than the dimensions given by Geitler (1932) for C. willei (6-6.5 µm). In this respect, the Nova Scotian specimens are closer to Cyanothrix cavanillesii Gonz.-Guerr., with cells 4-4.5 µm broad (Desikachary 1959), but this entity characteristically is much shorter than the Pomquet 'filaments', which frequently exceed 500 µm in length. While this length is also greater than that reported for both C. willei and C. primaria Gardn. (Geitler 1932), both width and length of the Pomquet plants are well within the limits described for J. pellucida (Desikachary 1959; Drouet & Daily 1956).

*Microcrocis geminata (Lagerh.) Geitl.
Ecophene: Holopedia sabulicola (Lagerh.) Kirchn. (Fig 13,14)
On mud flats below the zone of Spartina alterniflora Loisel.; Kingsport, Kings Co.; rare, September.

CHAMAESIPHONALES

Chamaesiphonaceae

Entophysalis conferta (Kütz). Dr. & Daily
Ecophenes: *Dermocarpa olivacea (Reinsch) Tilden (Fig 15)
*D. rosea Batt. (Fig 16)
*Xenococcus cladophorae (Tilden) S. & G. (Fig 17)
Supralittoral to sublittoral zones, on various algae and Ruppia L., in sheltered bays, marsh pans and tidepools, and on exposed coasts; Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; Gulliver Cove, Digby Co.; Herring Cove, Ketch Harbour, Sandy Cove, and Shag Bay, Halifax Co.; November-March, June, July, September.
Previous records in Nova Scotia: Collins (1904), as D. prasina (Reinsch) Born. & Flah.; Drouet and Daily (1956), ecophenes not specified; from marine habitats.

Entophysalis deusta (Menegh.) Dr. & Daily
Ecophenes: *Dermocarpa violacea Crouan (Fig 18)
*Gloeocapsa crepidinum Thur. ex Born. & Thur. (Fig 19)
*Pleurocapsa minuta Geitl. (Fig 20)
On mussel shells, submerged wood, and beneath Ralfsia verrucosa (Aresch.) J. Ag. on stones; Pomquet Harbour, Antigonish Co.; Black Rock, Halifax Co.; February, April, August, October.
Previous records in Nova Scotia: Drouet and Daily (1956), ecophenes not specified but habitat marine; Stephenson and Stephenson (1954), as E. deusta sensu stricto.

NOSTOCALES

Oscillatoriaceae

*Arthrospira brevis (Kütz.) Dr.
Ecophene: Oscillatoria brevis (Kütz.) Gom. (Fig 21)
In exposed turf of Spartina alterniflora at lower edge of salt marsh; Grand Pre and Kingsport, Kings Co.; rare, July, August.
Only scattered trichomes were found, in samples of the turf.

Microcoleus lyngbyaceus (Kütz.) Crouan frat. ex Gom.

Ecophenes: Lyngbya aestuarii [(Mert. in Jürg.) Liebm.] Gom. (Fig 22)

*L. confervoides (C. Ag.) Gom. (Fig 23)

*L. semiplena [(C. Ag.) J. Ag.] Gom. (Fig 24)

*Oscillatoria articulata Gardn. (Fig 25)

*O. corallinae [(Kütz.) Gom.] Gom. (Fig 26)

*O. margaritifera (Kütz.) Gom. (Fig 27)

Supralittoral to sublittoral, on mud, wood, and various algae in salt marshes and sheltered bays, or floating in marsh pans with other algae; Crystal Cliffs and Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; Waugh Island, Cumberland Co.; Durell Island, Guysborough Co.; Herring Cove and Sandy Cove, Halifax Co.; Grand Pré and Kingsport, Kings Co.; Boat Harbour, Pictou Co.; Bone Island, Victoria Co.; common and widespread, January, March, June-October, December.

Previous records in Nova Scotia: Drouet (1968), ecophenes unspecified.

This species was found wherever salt marsh habitats occur, and varied in abundance from isolated trichomes in algal mixtures to cohesive, nearly pure benthic turf. The prevalent ecophene was L. confervoides, although L. aestuarii and L. semiplena were occasionally locally common. O. margaritifera became abundant in pans at Barrachois Harbour in July 1974 and sublittorally in Pomquet Harbour during August 1974, when it formed slippery brownish-black masses around Chorda filum (L.) Stackh. and Zostera. The smaller ecophenes O. articulata and O. corallinae were collected as adherents to larger algae in sheltered situations.

The inclusion of O. corallinae in M. lyngbyaceus (Drouet 1968) indicates that the type material possesses granulated septa, although many descriptions of this taxon (Desikachary 1959; Frémy 1929-33; Geitler 1932; Setchell & Gardner 1919) state the contrary. Trichomes with granulated septa are usually identified in the literature as O. nigroviridis, which differs from O. corallinae essentially in only this respect. However, Drouet (1968) assigns O. nigroviridis to Porphyrosiphon, a genus which lacks granules on the septa, and this is corroborated by the original description of the former taxon (Harvey 1851, Pl. 251-A). Moreover, Carter (1933) illustrates granulated septa for both taxa, and Umezaki (1961) reports that granules sometimes disappear from the septa of O. nigroviridis. It thus appears that O. corallinae and O. nigroviridis have been confused in the literature. Possibly the slightly thickened outer wall of the terminal cell, usually reported for O. nigroviridis but fundamentally lacking in Porphyrosiphon (Drouet 1968), is also an error. Thus, contrary to most treatments, we reserve O. corallinae for trichomes with granulated septa and thickened terminal membranes, and O. nigroviridis for those without these characteristics but otherwise identical. As we have found the two taxa together, it is possible that our specimens of O. nigroviridis (see below) are in fact immature O. corallinae.

*Oscillatoria lutea C. Ag. ex Gom.

Ecophene: Lyngbya lutea [(C. Ag.) Gom.] Gom. (Fig 28)

In algal turf of Spartina patens zone, or mixed with Calothrix crustacea in loose crusts on moderately sheltered, high littoral stones; Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; rare, June, August, September.

Oscillatoria princeps Vaucher

Ecophene: *Plectonema wollei Farl. ex Gom. (Fig 29)

On outer edge of Spartina alterniflora turf; Pomquet Harbour, Antigonish Co.; uncommon, August.

Although apparently not widespread, P. wollei was common and well-developed in Pomquet Harbour, as small greenish-black webby masses. The specimens are narrower than P. wollei as described by several authors (Desikachary 1959; Geitler 1932; Prescott 1951), and differ also in their marine habitat. However, they agree well in both size and habitat with the description given by Schwabe (1960).

Oscillatoria submembranacea Ardiss. & Straff. ex Gom.

Ecophene: *Symploca funicularis S. & G. (Fig 30,67)

In salt marshes, mixed with other small algae at upper levels in turf of Spartina patens and Juncus gerardi Loisel., or matted along drainage ditches; Grand Pré and Kingsport, Kings Co.; occasional to common, July, August, October, December (probably year-round).

Previous record in Nova Scotia: Drouet (1968), ecophene unspecified, in freshwater.

Two growth habits were observed: at higher levels, O. submembranacea occurred primarily as scattered filaments among other algae; at lower levels, and particularly at the outfall of a drainage channel at Kingsport, these filaments were aggregated in dense, cohesive mats and tufts characteristic of Symploca. High-level filaments differed from those at lower levels only in having slightly narrower trichomes and thinner, subgelatinous sheaths suggestive of Phormidium. However, clones from both levels were morphologically identical in culture (Bird, unpubl), and we surmise that only the S. funicularis ecophene was present, despite absence of the characteristic tufted growth habit in upper levels of the marsh.

Trichomes of the Nova Scotian specimens of S. funicularis are considerably broader (7-10 μm) than those described by Setchell and Gardner (1919; 4.5-5 μm), and lack a diffluent sheath, but are comparable with Webber's (1967) concept of the taxon. As culture studies indicated trichomal width and consistency of sheath to be variable features, it appears that S. funicularis in nature was growing under conditions conducive to robust development, and that Webber's and the present concept of the ecophene is justified.

*Porphyrosiphon kurzii (Zeller) Dr.

Ecophene: Microcoleus acutirostris Gom. (Fig 31)

Scattered on mudbanks below salt marshes, or entangled with small low-littoral algae in sheltered situations; Pomquet Harbour, Antigonish Co.; Grand Pré, Kings Co.; uncommon, July, August, October, December.

Trichomes of the Nova Scotian specimens generally are narrow for M. acutirostris, being mostly 7-8 µm broad; however, they also lack the abrupt taper and regular, short cells of the comparably small ecophene M. weeksii S. & G. (Setchell & Gardner 1919). More typical trichomes 9.5-11 µm broad were found at Grand Pré in October.

Porphyrosiphon kurzii is an intertidal species of warm-temperate and tropical seas (Drouet 1968). Its occurrence in Nova Scotia is possibly linked with warm summer temperatures in Pomquet Harbour and Minas Basin relative to outlying coastal waters (Bird et al 1976; Bousfield & Thomas 1975).

Porphyrosiphon notarisii (Menegh.) Kütz. ex Gom.

Ecophenes: *Oscillatoria chalybea Mert. (Fig 33)
O. nigroviridis (Thw. in Harv.) Gom. (Fig 32)

In salt marshes, as scattered short filaments or thin mats in algal turf of Juncus and Spartina swards, or on unconsolidated mud beneath S. alterniflora; Pomquet Harbour, Antigonish Co.; Grand Pré and Kingsport, Kings Co.; uncommon, July, August.

Schizothrix arenaria (Berk.) Gom.

Ecophene: *Microcoleus chthonoplastes [(Mert. in Hornem.) Thur.] Gom. (Fig 34)

High to low littoral levels in salt marshes, mixed with other small algae in turf under Juncus and Spartina, rarely among detritus in pans and wet depressions; Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; Grand Pré and Kingsport, Kings Co.; occasional to locally common, May-October, December (rare).

Previous record in Nova Scotia: Drouet (1968), ecophene unspecified.

In Nova Scotia, the ecophene M. chthonoplastes is a characteristic constituent of algal turf in salt marshes, but does not attain the abundance or dominance described by Carter (1933) in Britain. Rather, it has been observed as locally common, at best, in the upper reaches of Spartina alterniflora zones at Grand Pré and Kingsport during July and August, and in open patches in S. patens swards at Pomquet Harbour in May.

Schizothrix calcicola (C. Ag.) Gom. ex Gom.

Ecophenes: *Lyngbya epiphytica Hieron. ex Kirchn. (Fig 35)
*L. holdenii Forti (Fig 36)
*L. infixa Fremy (Fig 37)
*L. nordgaardii Wille (Fig 38)
*Oscillatoria amphigranulata van Goor (Fig 39)
*Phormidium angustissimum W. & G. S. West (Fig 40)
*Ph. frigidum Fritsch (Fig 41)
Ph. mucicola Naum. & Hub.-Pestalozzi (Fig 42)
*Plectonema battersii Gom. (Fig 43)
*Pl. terebrans (Born. & Flah.) Gom. (Fig 44)

On mud, wood, Zostera and various algae, on and in mollusc shells and barnacle tests, usually mixed with other algae in turf or crusts, seldom in pure masses, in all intertidal levels of salt marshes and sheltered bays to extreme high water, often in the supralittoral zone of

exposed coasts, occasionally sublittoral; Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; Sandy Cove and Westport, Digby Co.; Black Rock, Herring Cove, Lawrencetown, Peggy's Cove and Sandy Cove, Halifax Co.; Grand Pré and Kingsport, Kings Co.; common, year-round.

Previous records in Nova Scotia: Drouet (1968), ecophenes not specified; Stephenson and Stephenson (1954), as Plectonema calothrichoides Gom. and Pl. nostocorum Born. ex Gom.

This ubiquitous species exists in so many very similar ecophenes that it is frequently difficult, if not impossible, to distinguish them. Also, filiform bacteria may strongly resemble S. calcicola. The ecophenes listed above represent the species as it appeared in nature, regardless of variability, in culture, of some traditional diagnostic features, particularly the nature of the sheath.

Three of the present ecophenes, L. epiphytica, Ph. angustissimum and Ph. frigidum, are usually freshwater algae (Geitler 1932).

*Schizothrix tenerrima (Gom.) Dr.

Ecophene: Microcoleus tenerrimus Gom. (Fig 45)

Mixed with Vaucheria sp. beneath Spartina patens in salt marsh, or matted with other cyanophytes on barnacle tests; Barrachois Harbour, Colchester Co.; rare, June, July.

Spirulina subsalsa Oerst. ex Gom.

Ecophene: S. subsalsa sensu stricto (Fig 46)

Although previously recorded from Nova Scotia (McLachlan & Edelstein 1970-71), S. subsalsa is so frequently encountered that it is worthwhile to comment on its general occurrence. Its presence in the littoral zone is apparently restricted to late spring and summer (May-September), when it is a usual minor constituent of algal turf in salt marshes, and sometimes forms small, nearly pure patches and films on unconsolidated mud in these habitats. In the upper sublittoral zone of quiet bays and barachois, it often forms numerous small clots and films on benthos during July and August. Winter occurrences have been noted at greater depths in these situations. Additionally, S. subsalsa has been observed as abundant in deep water of Bras d'Or Lake, with a striking rose color instead of its customary blue-green hue (R. Hooper, personal communication).

Nostocaceae

Anabaena inaequalis (Kütz.) Born. & Flah. (Fig 47)

Mixed with other algae in turf beneath Spartina patens; Pomquet Harbour, Antigonish Co.; rare, June.

As akinetes are essential to the identification of species of Anabaena, their presence is implied in this and the following three records.

Anabaena sphaerica Born. & Flah. (Fig 48)

In colonies of Coccochloris stagnina in salt marsh pan; Pomquet Harbour, Antigonish Co.; rare, July.

*Anabaena subcylindrica Borge (Fig 49)

Mixed with other filamentous cyanophytes on unconsolidated mud beneath Spartina alterniflora; Grand Pré, Kings Co.; rare, July.

*Anabaena torulosa [(Carm. in Harv.) Lagerh.] Born. & Flah. (Fig 50)

In salt marshes and protected bays: on unconsolidated mud, in algal turf beneath Spartina alterniflora and S. patens, in pans, occasionally forming nearly pure masses on shallow benthos; Crystal Cliffs and Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; Grand Pré and Kingsport, Kings Co.; Red Islands, Richmond Co.; common and occasionally abundant, July-October.

This is the most common species of Anabaena in Nova Scotia, with July and August the period of maximum abundance. In a notable occurrence in Pomquet Harbour, July 1974, small clots of A. torulosa were abundant in sheltered shallows and frequently cast up on Spartina turf, often as masses of akinetes. The species has not been observed thus far in winter collections.

Calothrix crustacea Thur. ex Born. & Flah.†

Ecophenes: *Calothrix aeruginea [(Kutz.) Thur.] Born & Flah. (Fig 51)
*Microchaete aeruginea Batt. (Fig 52,53)
*M. grisea (Thur.) Born & Flah. (Fig 54)
*Rivularia nitida (C. Ag.) Born. & Flah. (Fig 55, 56,57)

In salt marshes and quiet bays; on other algae, Ruppia L., old Zostera leaves, Spartina debris and wood, at times on stones or ground and then usually abundant; Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; occasional to common, year-round.

Previous records in Nova Scotia: Bird (1973), as C. scopulorum [(Web. & Mohr) C. Ag.] Born. & Flah.; Drouet (1973), ecophenes not specified; Edelstein and McLachlan (1966), as C. scopulorum; McLachlan and Edelstein (1970-71), as C. confervicola [(Roth) C. Ag.] Born. & Flah. and Rivularia atra (Roth) Born. & Flah.; Stephenson and Stephenson (1954), as C. scopulorum, C. vivipara (Harv.) Born. & Flah. and R. atra. Fan (1956) included several Nova Scotian collections in his revised concepts of C. confervicola and C. crustacea (Thur.) Born. & Flah.

As the number of prior records indicates, C. crustacea is one of the most conspicuous and abundant cyanophytes in Nova Scotia. The widespread ecophenes C. crustacea sensu stricto†† and C. scopulorum are major constituents of a characteristic supralittoral black zone on rocky, exposed coasts (cf Stephenson & Stephenson 1954), and C. crustacea is also occasionally epiphytic on benthic angiosperms and algae in sheltered bays and salt marshes. Rivularia atra is frequent on protected rocky shores, in the upper intertidal zone above fucoids or in permanent pools. Rivularia nitida occasionally occurs as closely aggregated, small bullate thalli in open patches of Juncus and Spartina along marshy shores. Calothrix confervicola is a common epiphyte in sheltered waters, particularly during summer, while C. aeruginea and Microchaete are less common epiphytes observed from May to October.

†=C. crustacea Schousb. & Thur. (Drouet 1973).
††Not C. crustacea Wolle, =Scytonema hofmannii (Drouet 1973).

Calothrix parietina (Näg.) Thur. ex Born. & Flah.

Ecophene: * Rivularia biasolettiana [Menegh.] Born. & Flah. (Fig 58,59)

On Zostera debris in salt marsh pans; entangled with Rhizoclonium in sheltered water; Pomquet Harbour, Antigonish Co.; Waugh Island, Cumberland Co.; uncommon, July, October.

Previous records from Nova Scotia: Geitler (1932), as R. bornetiana Setch., from a salt marsh. As the exsiccata and reference cited by Geitler refer to specimens from Rhode Island, this record appears to be in error. Fan (1956) included collections by the Stephensons from St. Margaret's Bay, N.S. in his reappraisal of C. parietina; however, in view of the marine habitat studied by these authors (Stephenson & Stephenson, 1954), it seems likely that these collections are assignable to C. crustacea, although they are not the same Nova Scotian specimens as cited under C. crustacea by Drouet (1973).

Calothrix parietina is primarily a fresh-water species, seldom found in brackish environments (Drouet 1973). Rivularia biasolettiana, a mainly freshwater ecophene, has been reported to penetrate saline habitats (Frémy 1929-33; Parke & Dixon 1968, 1976; Setchell & Gardner 1919).

Nodularia harveyana (Thw. in Harv.) Thur. ex Born. & Flah. (Fig 60)

Salt marshes, in algal turf under Spartina and Juncus, occasionally in pans; Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; Kingsport, Kings Co.; uncommon, June-August.

Akinetes were not observed in any of the Nova Scotian specimens.

*Nodularia spumigena Mert. in Jürg. ex Born. & Flah. (Fig 61)

Mixed with Anabaena torulosa near shore in a protected basin; Pomquet Harbour, Antigonish Co.; rare, July, with akinetes.

*Nostoc punctiforme (Kütz.) Hariot (Fig 62,63)

In all levels of salt marshes, mostly on decaying grasses and forbs, or wood; often in pans or in algal mats floating in quiet backwaters; Pomquet Harbour, Antigonish Co.; Barrachois, Colchester Co.; Kingsport, Kings Co.; occasional, July-October, December; hormogonia observed in October.

Scytonema hofmannii C. Ag. ex Born. & Flah.

Ecophene: Tolypothrix tenuis (Kütz.) Born. & Flah. (Fig 64)

Among Calothrix crustacea (Rivularia nitida) on upper levels of marshy shores, and sublittoral to 3 m depth in sheltered bays; Pomquet Harbour, Antigonish Co.; rare, October, December.

Previous record in Nova Scotia: Drouet (1973), unspecified ecophene from a freshwater habitat.

STIGONEMATALES

Nostochopsidaceae

*Mastigocoleus testarum Lagerh. ex Born. & Flah. (Fig 65)

In empty shells of molluscs and barnacles, littoral to upper sublittoral zones in sheltered bays; Pomquet Harbour, Antigonish Co.; Barrachois Harbour, Colchester Co.; uncommon, July-October, probably year-round.

REFERENCES

BELL, H. P. and MACFARLANE, C. 1933. The marine algae of the Maritime Provinces of Canada. I. List of species with their distribution and prevalence. Can. J. Res. 9: 265-79.

BIRD, C. J. 1973. Aspects of the life history and ecology of Porphyra linearis (Bangiales, Rhodophyceae) in nature. Can. J. Bot. 51: 2371-79.

BIRD, C. J., EDELSTEIN, T. and MCLACHLAN, J. 1976. Investigations of the marine algae of Nova Scotia. XII. The flora of Pomquet Harbour. Can. J. Bot. 54: 2726-37.

BOUSFIELD, E. L. and THOMAS, M.L.H. 1975. Post-glacial changes in distribution of littoral marine invertebrates in the Canadian Atlantic region. Proc. N.S. Inst. Sci. 27, (3rd supp): 47-60.

CARTER, N. 1933. A comparative study of the algal flora of two salt marshes. Part II. J. Ecol. 21: 128-208.

COLLINS, F. S. 1904. A sailor's collection of algae. Rhodora 6: 181-82.

DESIKACHARY, T. V. 1959. Cyanophyta. Academic Press, New York.

DROUET, F. 1968. Revision of the classification of the Oscillatoriaceae. Philadelphia Acad. Nat. Sci. Monogr. 15.

DROUET, 1973. Revision of the Nostocaceae with Cylindrical Trichomes. Hafner Press, New York.

DROUET, F. and DAILY, W. A. 1956. Revision of the coccoid Myxophyceae. Butler Univ. Bot. Stud. 12.

EDELSTEIN, T. and MCLACHLAN, J. 1966. Winter observations on species of Porphyra from Halifax County, Nova Scotia. Proc. Int. Seaweed Symp. 5: 117-22.

EDELSTEIN, T. and MCLACHLAN, J. 1967a. Investigations of the marine algae of Nova Scotia. III. Species of Phaeophyceae new or rare to Nova Scotia. Can. J. Bot. 45: 203-10.

EDELSTEIN, T. and MCLACHLAN, J. 1967b. Investigations of the marine algae of Nova Scotia. IV. Species of Chlorophyceae new or rare to Nova Scotia. Can. J. Bot. 45: 211-14.

EDELSTEIN, T., MCLACHLAN, J. and CRAIGIE, J.S. 1967. Investigations of the marine algae of Nova Scotia. II. Species of Rhodophyceae new or rare to Nova Scotia. Can. J. Bot. 45: 193-202.

FAN, K. C. 1956. A revision of Calothrix Ag. Rev. Algol. N.S. 2: 154-78.

FRÉMY, P. 1929-33. Cyanophycées des cotes d'Europe. Mem. Soc. Nat., Sci. Nat. Math. Cherbourg, 41.

GEITLER, L. 1932. Cyanophyceae. Rabenhorst Kryptogamenflora, 14. Leipzig.

HABEEB, H. and DROUET, F. 1948. A list of fresh water algae from New Brunswick. Rhodora, 50: 67-71.

HARVEY, W. H. 1851. Phycologica Britannica III. Reeve and Benton, London.

HUGHES, E. O. 1949. Fresh-water algae of the Maritime Provinces. Proc. N.S. Inst. Sci. 22(2): 1-63.

KLUGH, A. B. 1917. The marine algae of the Passamaquoddy region, New Brunswick. Contr. Can. Biol. 1915-1916: 79-84.

KLUGH, A. B. 1921. A new genus and three new species of algae from the Miramichi River. Contr. Can. Biol. 1918-1920: 181-83.

KLUGH, A. B. 1927. The ecology, food relations, and culture of fresh-water Entomostraca. Trans. R. Can. Inst. 16: 15-98.

MACFARLANE, C. I. and MILLIGAN, G. M. 1966. Marine algae of the Maritime Provinces of Canada. A preliminary check list. N.S. Res. Found., Seaweeds Div., Dartmouth, (mimeogr.).

MCLACHLAN, J. and EDELSTEIN, T. 1970-71. Investigations of the marine algae of Nova Scotia. IX. A preliminary survey of the flora of Bras d'Or Lake, Cape Breton Island. Proc. N.S. Inst. Sci. 27: 11-22.

PARKE, M. and DIXON, P. S. 1968. Check-list of British marine algae - second revision. J. Mar. Biol. Ass. U.K. 48: 783-832.

PARKE, M. and DIXON, P.S. 1976. Check-list of British marine algae - third revision. J. Mar. Biol. Ass. U.K. 56: 527-94.

PRESCOTT, G. W. 1951. Algae of the western Great Lakes area. Cranbrook Inst. Sci. Bull. 31.

SCHWABE, G. H. 1960. Zur Morphologie und Okologie einiger Plectonema-Arten. Nova Hedwigia, 2: 243-268.

SETCHELL, W. A. and GARDNER, N. L. 1919. The marine algae of the Pacific coast of North America. I. Myxophyceae. Univ. Calif. Publ. Bot. 8:1-138.

SMITH, M. W. 1938. A survey of Lake Jesse, Nova Scotia. Proc. N.S. Inst. Sci. 19: 253-263.

SMITH, M. W. 1946. A biological reconnaissance of ponds in the Prince Edward Island National Park. Acad. Nat. 2: 81-101.

SMITH, M. W. 1952. Limnology and trout angling in Charlotte County lakes, New Brunswick. J. Fish. Res. Bd. Can. 8: 383-452.

SOUTH, G. R. 1976. A check-list of marine algae of eastern Canada - first revision. J. Mar. Biol. Ass. U.K. 56: 817-843.

STAKER, R. D. 1976. Algal composition and seasonal distribution in the Dunk River system, Prince Edward Island. Nova Hedwigia, 27: 731-745.

STEPHENSON, T. A. and STEPHENSON, A. 1954. Life between tide-marks in North America. IIIA. Nova Scotia and Prince Edward Island: description of the region. J. Ecol. 42: 14-45.

TAYLOR, W. R. 1957. Marine Algae of the Northeastern Coast of North America. 2nd ed. Univ. Michigan Press, Ann Arbor.

UMEZAKI, I. 1961. The marine blue-green algae of Japan. Mem. Coll. Agric. Kyoto Univ. 83, Kyoto.

WEBBER, E. E. 1967. Blue-green algae from a Massachusetts salt marsh. Bull. Torr. Bot. Club, 94: 99-106.

FIGURE LEGENDS

Figs 1-69, binomials in parentheses are classical names of illustrated ecophenes. Unless otherwise indicated, scale bar = 10 µm.

Figs 1, 2. Agmenellum quadruplicatum (Merismopedia punctata), colonies differing in proximity of cells. Fig 3. Agmenellum thermale: Fig. 3, (Merismopedia glauca), portion of a colony. Figs 4, 5. Anacystis dimidiata (Chroococcus turgidus). Figs 6-10. Coccochloris stagnina: Fig 6, (Aphanothece stagnina); Fig. 7, 8, (Chroococcus minutus); Fig 9, (Microcystis litoralis); Fig 10, (M. pallida); only portions of colonies are illustrated in Fig. 6 and 10. Fig 11. Gomphosphaeria aponina (sensu stricto). Fig 12. Johannesbaptistia pellucida (Cyanothrix willei). Figs 13, 14. Microcrocis geminata (Holopedia sabulicola): Fig 13, surface aspect of part of a colony; Fig 14, sectional view, showing transverse striae.

Figs 15-17. Entophysalis conferta: Fig 15, (Dermocarpa olivacea); Fig 16, (D. rosea), with empty endosporangia and released endospores; Fig 17, (Xenococcus cladophorae) with endosporangium forming spores; E - endosporangium, Es - released endospores. Fig 18-20. Entophysalis deusta: Fig 18, (Dermocarpa violacea); Fig 19, (Gloeocapsa crepidinum); Fig 20, (Pleurocapsa minuta), with rudimentary filaments.

Fig 21. Arthrospira brevis (Oscillatoria brevis). Figs 22-23. Microcoleus lyngbyaceus: Fig 22, (Lyngbya aestuarii), showing discoid hormogonia and laminate sheath in the older portion of the filament; Fig 23, (L. confervoides); Fig 24, (L. semiplena); Fig 25, (Oscillatoria articulata); Fig 26, (O. corallinae); Fig 27, (O. margaritifera). Fig 28. Oscillatoria lutea (Lyngbya lutea). Fig 29. Oscillatoria princeps (Plectonema wollei). Fig 30. Oscillatoria submembranacea (Symploca funicularis) C-calyptra. Fig 31. Porphyrosiphon kurzii (Microcoleus acutirostris). Figs 32, 33. Porphyrosiphon notarisii: Fig 32, (Oscillatoria nigroviridis); Fig 33, (O. chalybea), with peripheral refractive inclusions.

Fig 34. Schizothrix arenaria (Microcoleus chthonoplastes) apex of filament with relatively few trichomes. Figs 35-44. Schizothrix calcicola: Fig 35, (Lyngbya epiphytica) on Microcoleus; Fig 36, (L. holdenii); Fig 37, (L. infixa) on Bangia; Fig 38, (L. nordgaardii) on Calothrix; Fig 39, (Oscillatoria amphigranulata); Fig 40, (Phormidium angustissimum); Fig 41, (Ph. frigidum); Fig 42, (Ph. mucicola), from empty sheaths of Microcoleus; Fig 43, (Plectonema battersii); Fig 44, (Pl. terebrans).

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Figs 5l-57. Calothrix crustacea: Fig 5l, (C. aeruginea); Fig. 52, 53, (Microchaete aeruginea); Fig 52, habit on Zostera; Fig 53, detail of several filaments; Fig 54, (M. grisea); Figs 55-57, (Rivularia nitida); Fig 55, young filament from surface of thallus; Fig 56, older filament with subapical meristematic zone (M) and young filament (F) forming; Fig 57, detail of base of older filament. Figs 58, 59. Calothrix parietina: (Rivularia biasolettiana): Fig 58, fascicle of filaments from a squashed thallus; Fig 59, detail of bases of filaments.

Fig 60. Nodularia harveyana. Fig 6l. Nodularia spumigena, with akinetes. Figs 62, 63. Nostoc punctiforme: Fig 62, detail of trichomes; Fig 63, hormogonium. Fig 64. Scytonema hofmannii (Tolypothrix tenuis). Fig 65. Mastigocoleus testarum.

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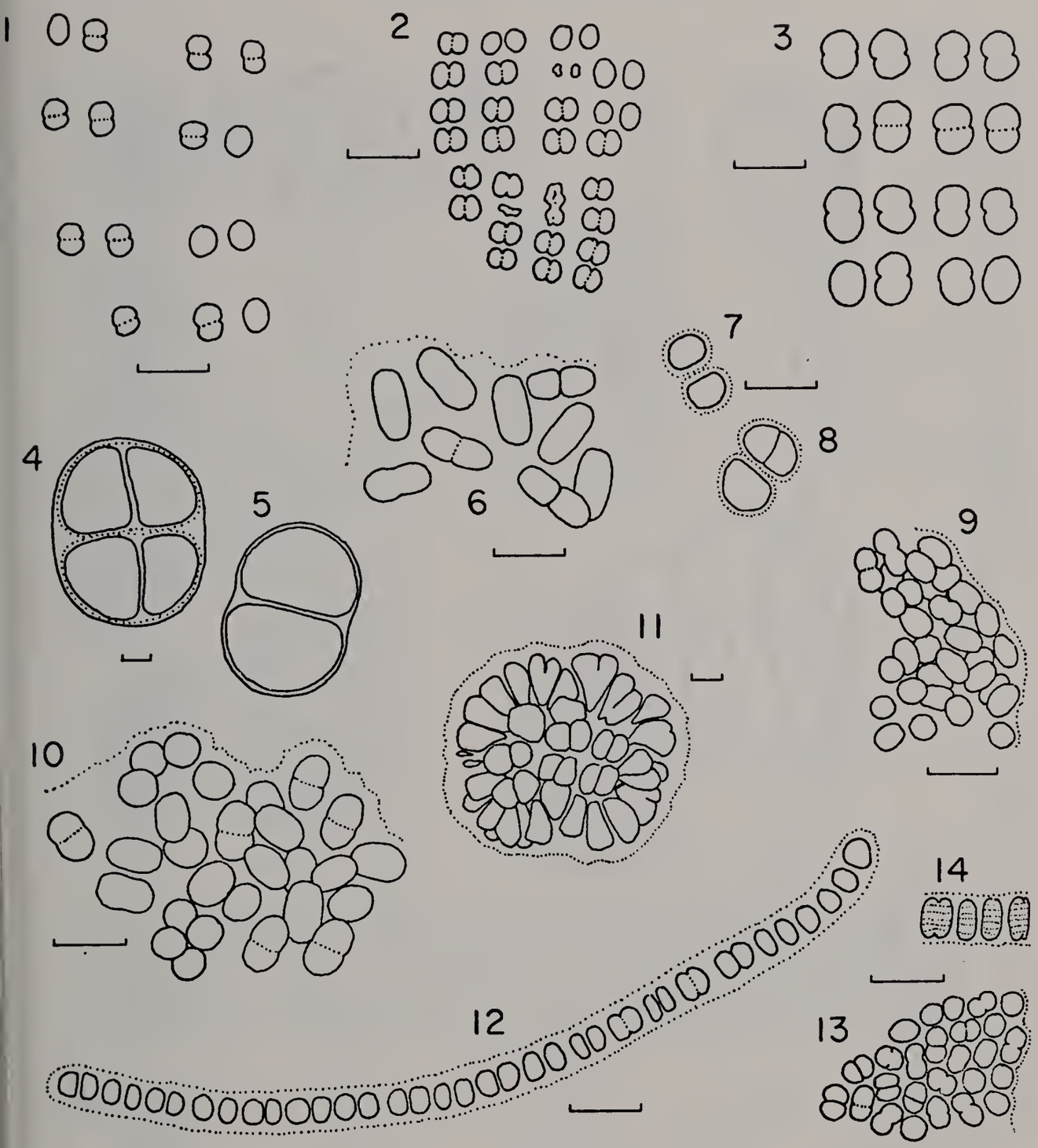
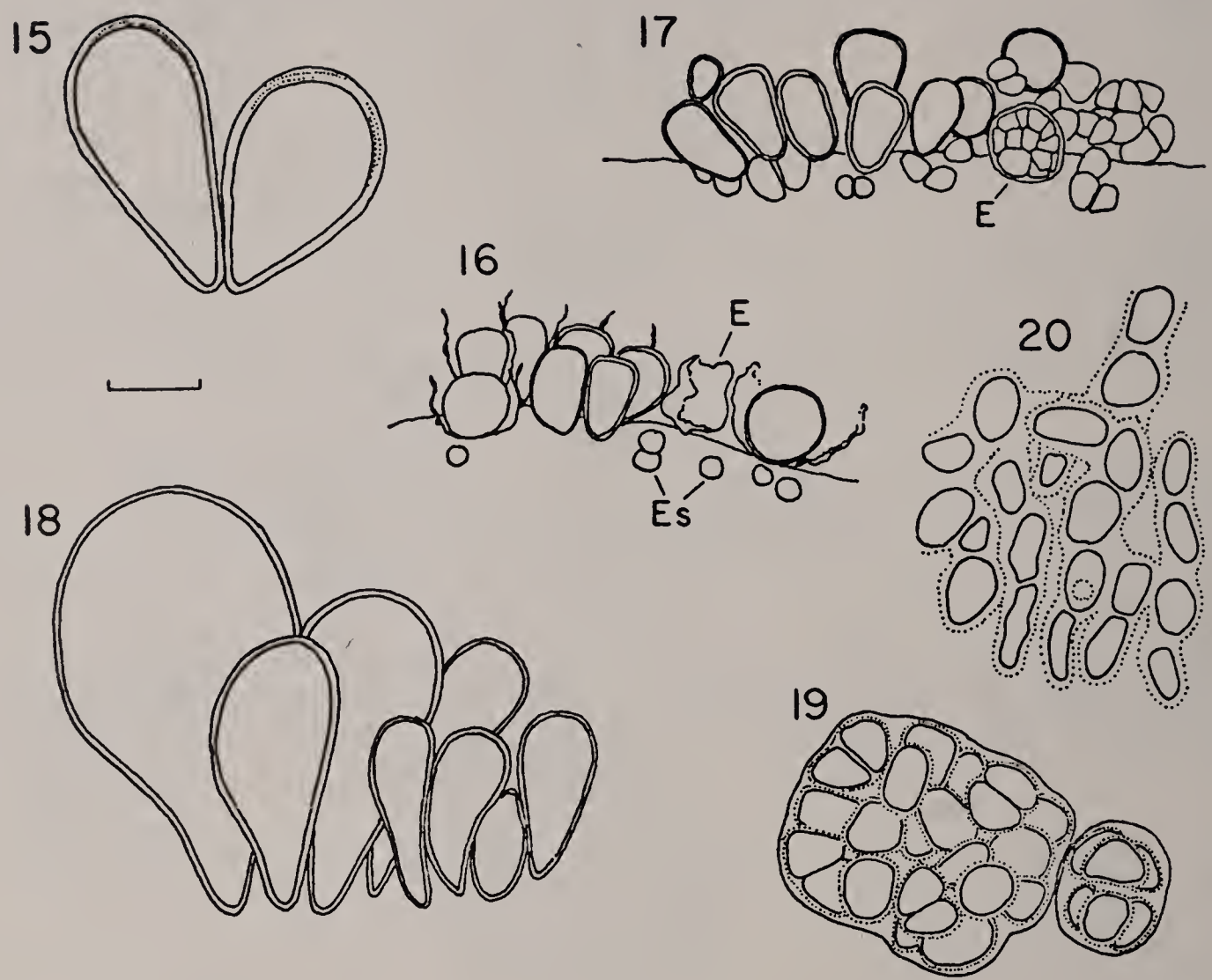


Figs 1-69, binomials in parentheses are classical names of illustrated ecophenes. Unless otherwise indicated, scale bar = 10 μm.

Figs 1, 2. Agmenellum quadruplicatum (Merismopedia punctata), colonies differing in proximity of cells. Fig 3. Agmenellum thermale: Fig. 3, (Merismopedia glauca), portion of a colony. Figs 4, 5. Anacystis dimidiata (Chroococcus turgidus). Figs 6-10. Coccochloris stagnina: Fig 6, (Aphanothece stagnina); Fig. 7, 8, (Chroococcus minutus); Fig 9, (Microcystis litoralis); Fig 10, (M. pallida); only portions of colonies are illustrated in Fig. 6 and 10. Fig 11. Gomphosphaeria aponina (sensu stricto). Fig 12. Johannesbaptistia pellucida (Cyanothrix willei). Figs 13, 14. Microcrocis geminata (Holopedia sabulicola): Fig 13, surface aspect of part of a colony; Fig 14, sectional view, showing transverse striae.



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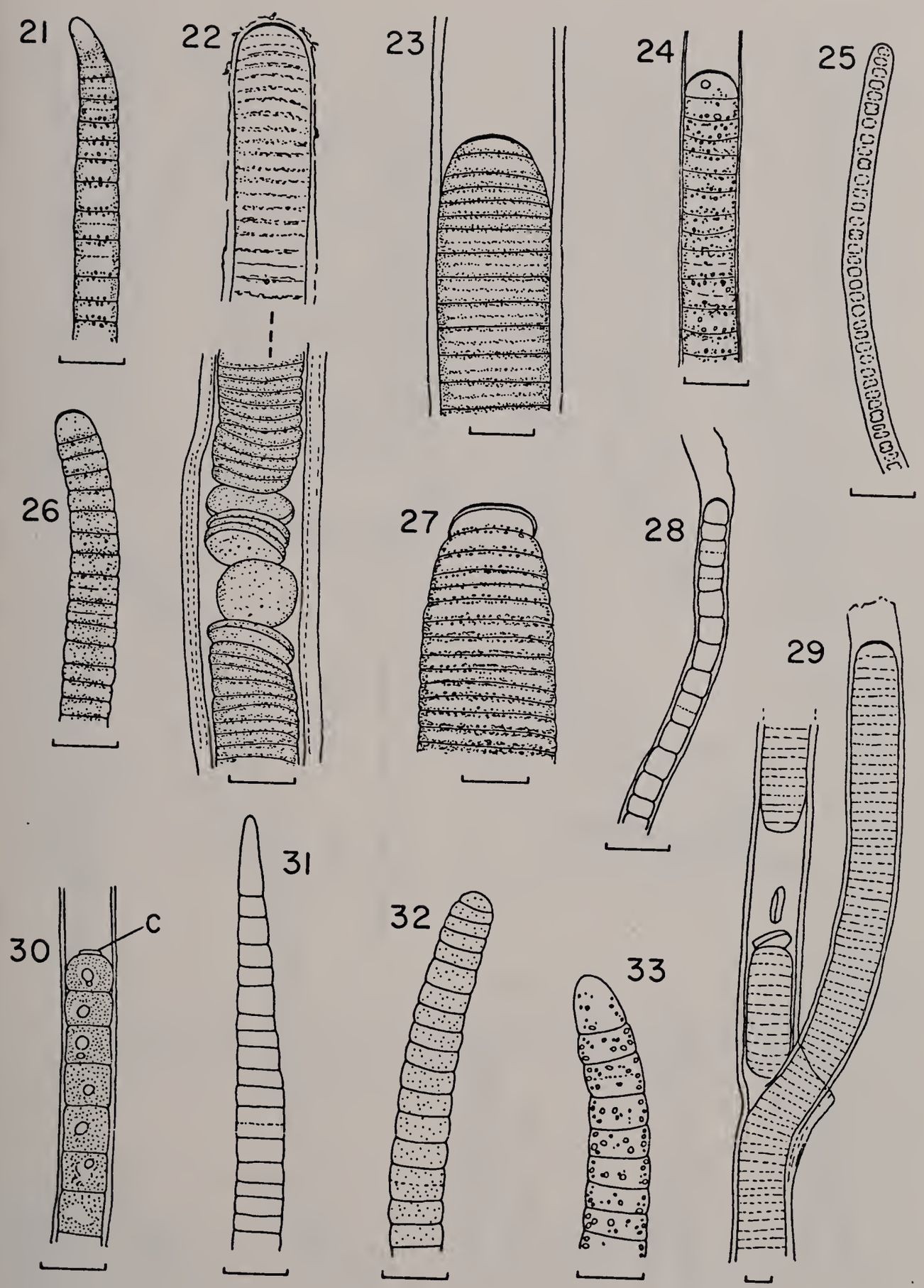
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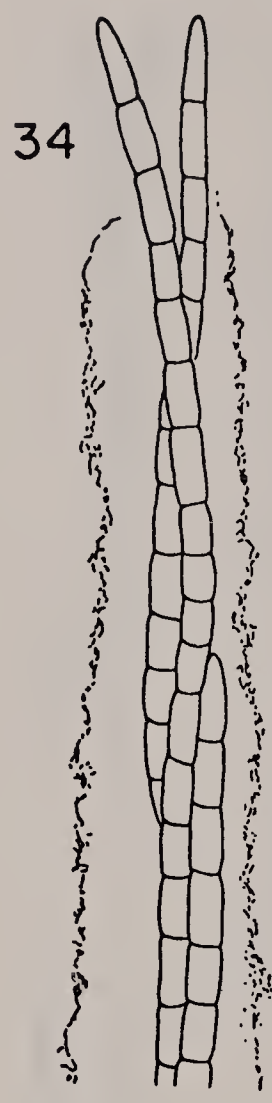
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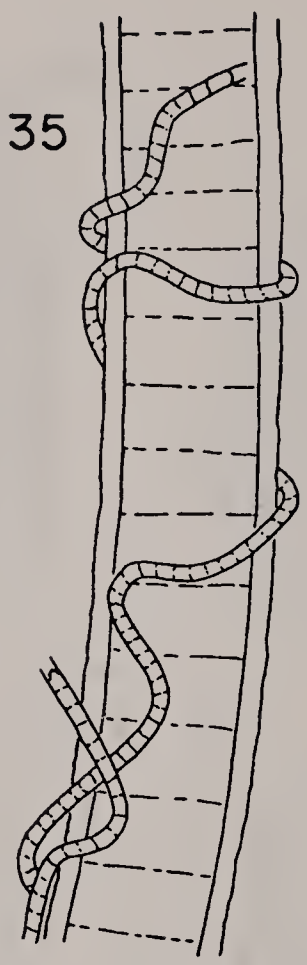
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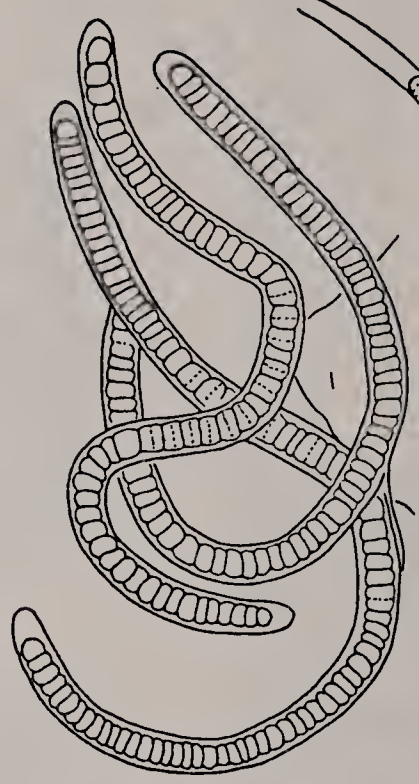
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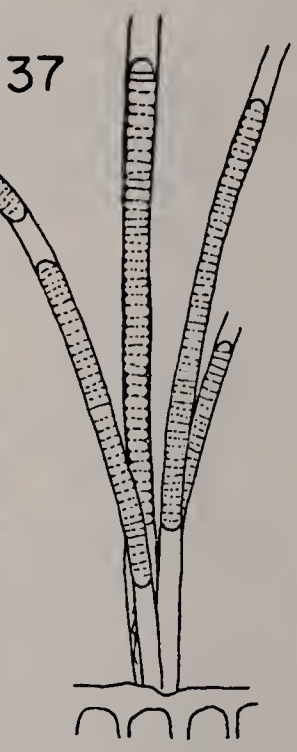
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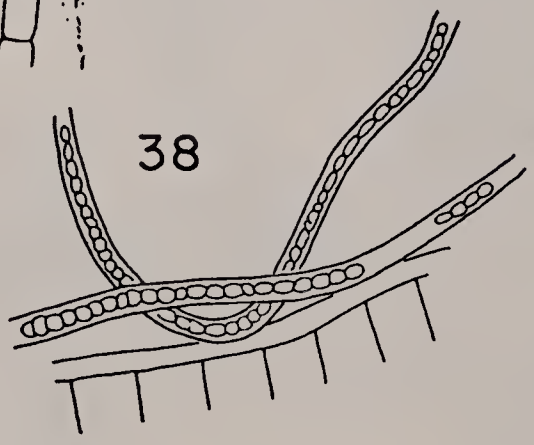
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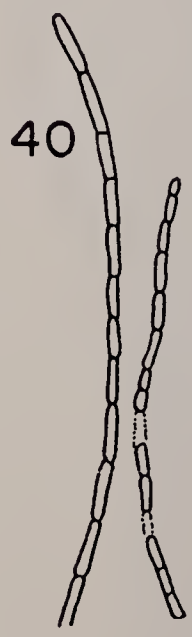
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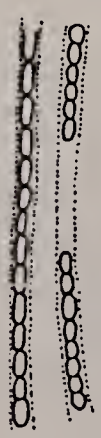
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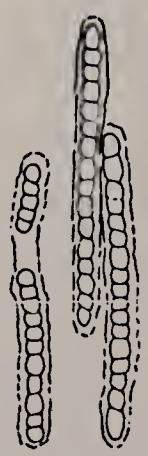
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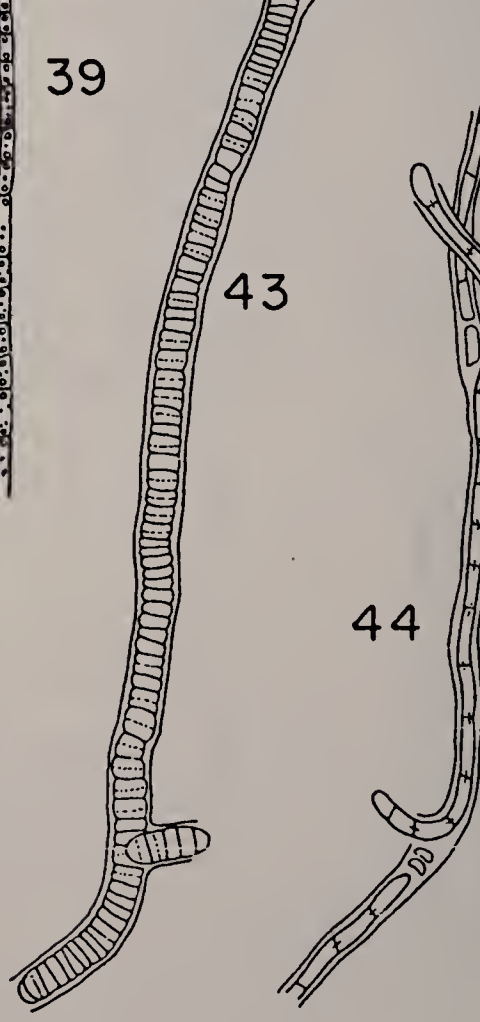
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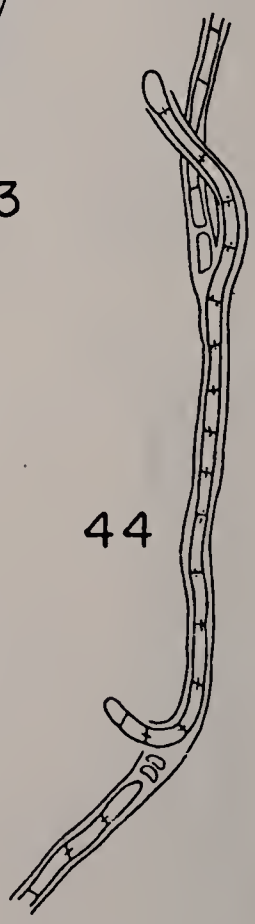
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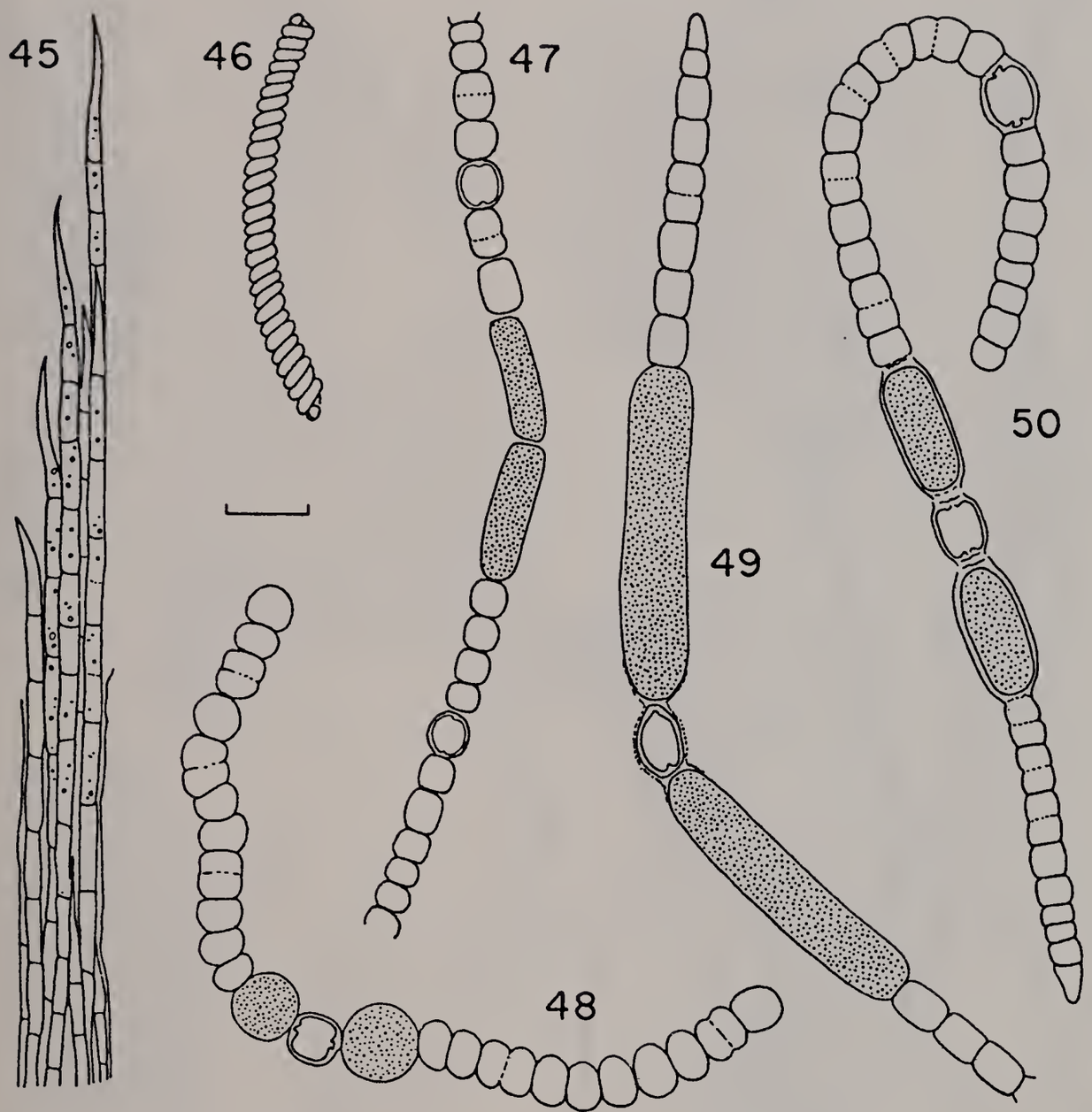

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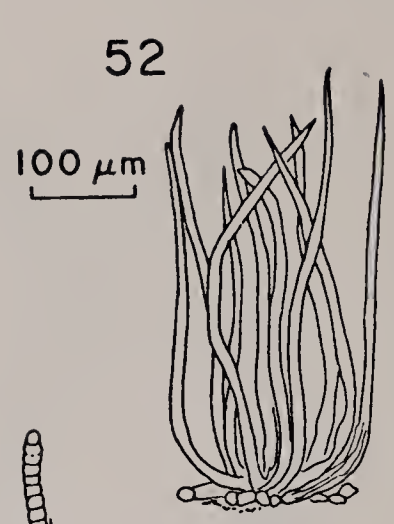
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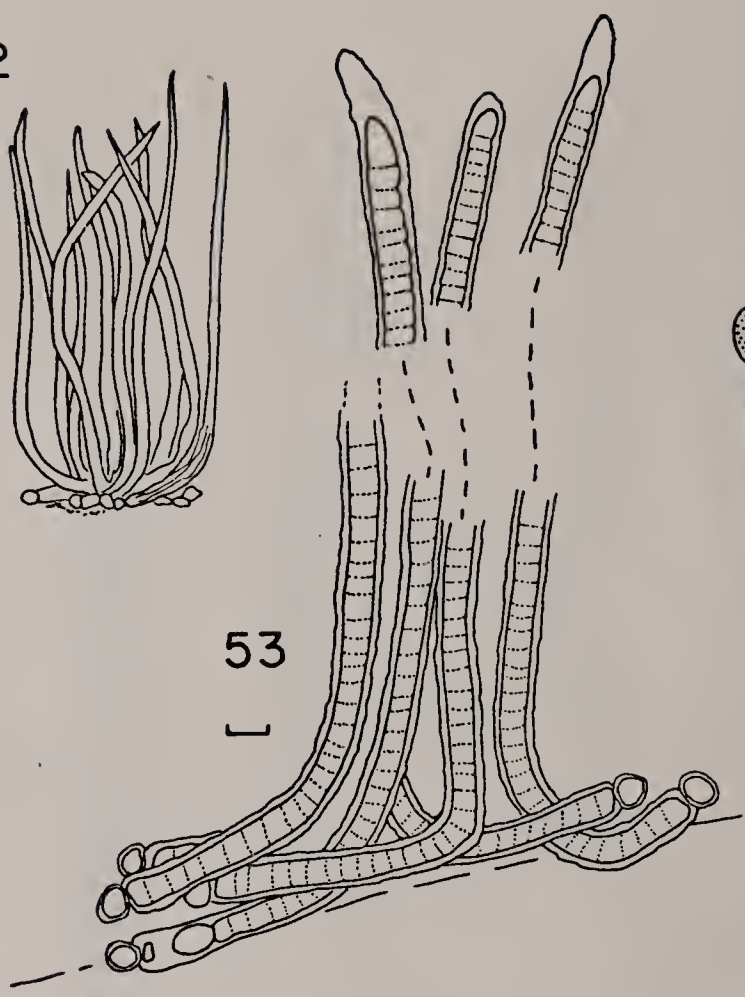
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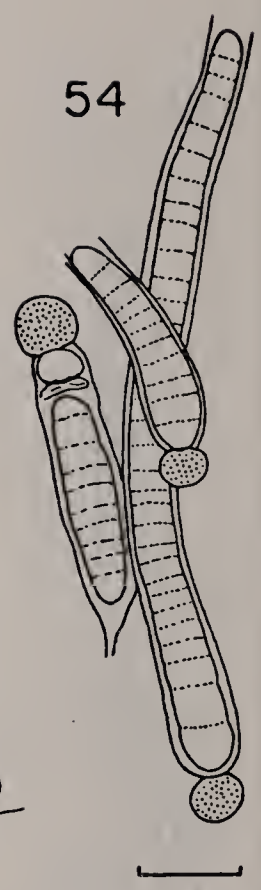
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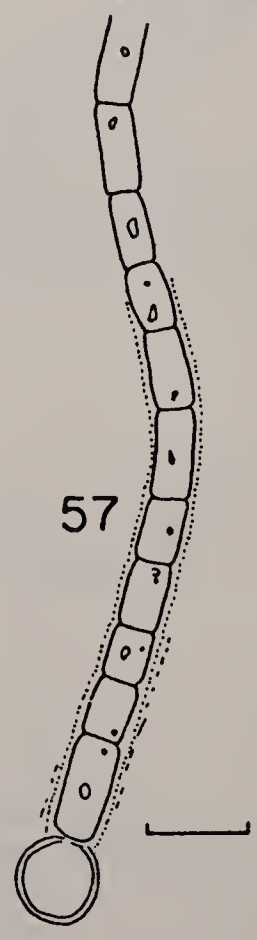
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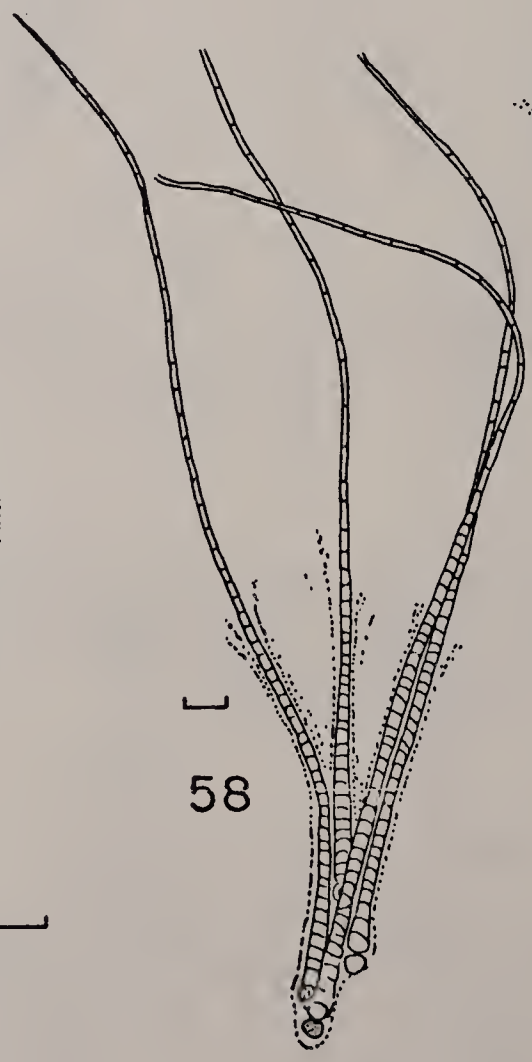
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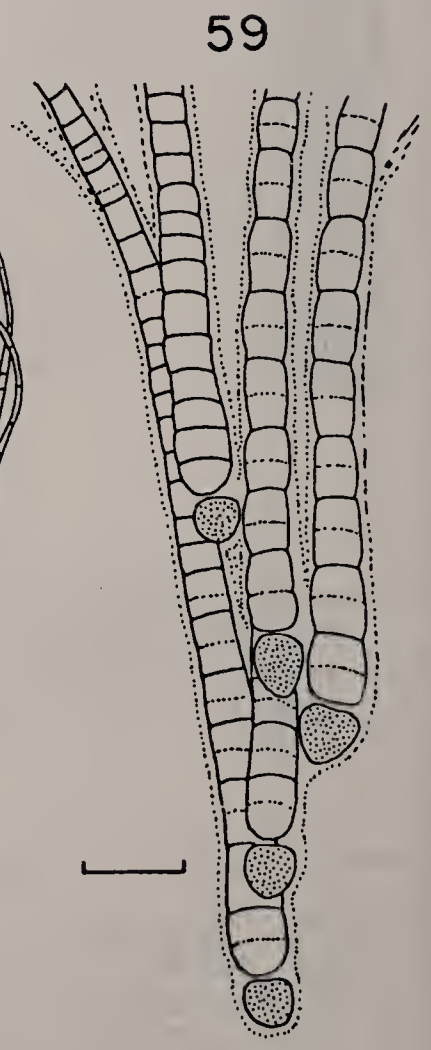
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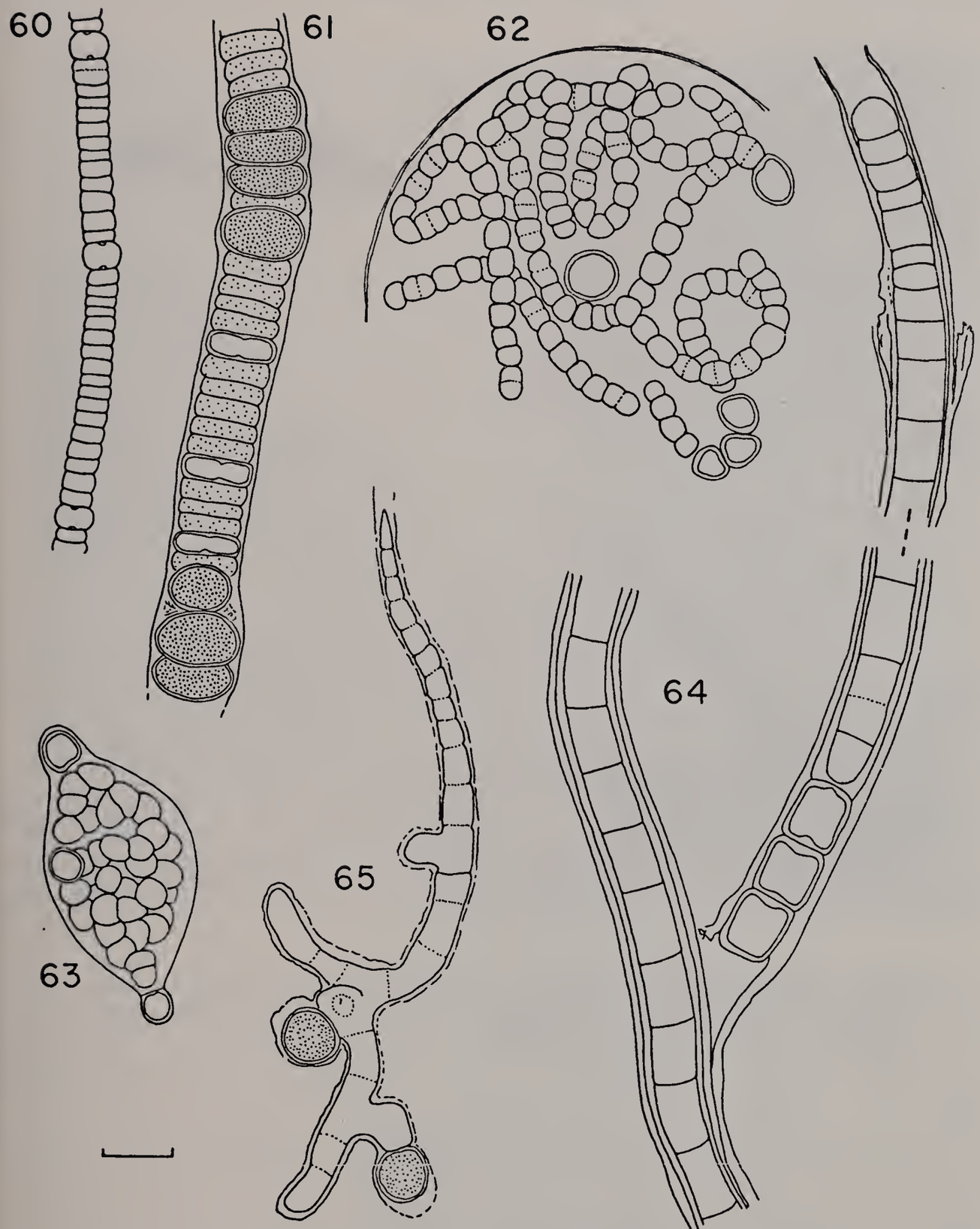

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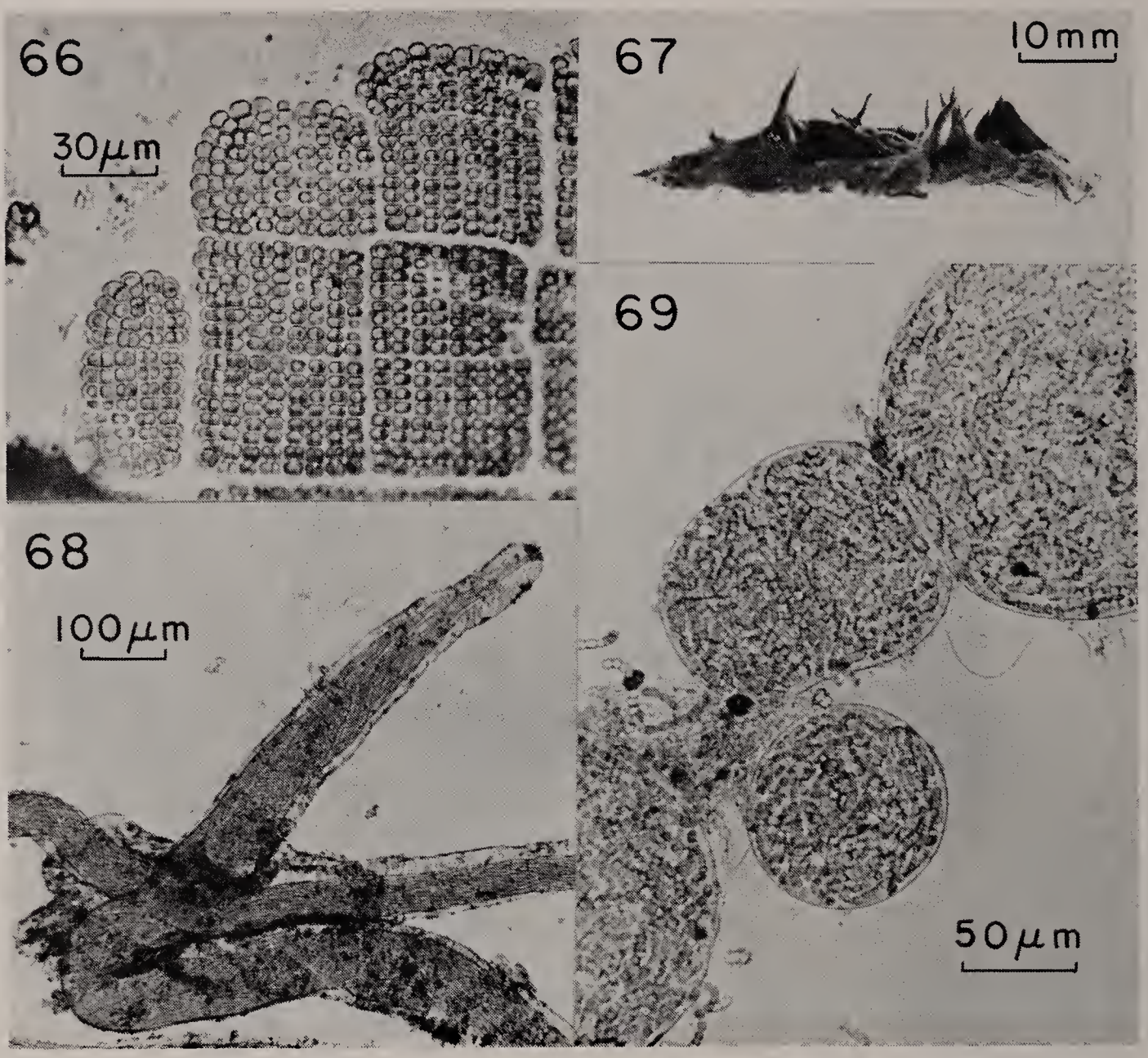

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NOVA SCOTIAN FLESHY FUNGI: A NEW ALBINO VARIANT OF *HYPOMYCES LACTIFLUORUM* (SCHW. ex FR.) TULASNE

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A new albino color variant of Hypomyces lactifluorum (Schw. ex Fr.) Tulasne is reported for the first time. Both the white and normal bright orange forms were collected within an area of 16 m^2, and were sporulating at the time. Because the microscopic characters of both variants are the same, a new taxon is not proposed.

INTRODUCTION

Hypomyces lactifluorum (Schw. ex Fr.) Tulasne is a common hypocrealean ascomycete found as a parasite in North America on mushrooms belonging to the family Russulaceae. The appearance of diseased mushrooms is so changed that they cannot be recognized as to species; however, the bright orange-red color of the parasite makes the parasitized carpophores one of the more conspicuous large fungi commonly found in the forests of Nova Scotia during summer and autumn.

In mid-September 1977, in the Gaspereaux Valley, Kings County, a group of Russulaceae parasitized by this ascomycete was found consisting of the normal orange-red form closely associated with specimens that were "white", while others were white with orange-red streaks, and still others orange-red with white streaks. The specimens were found in an area 16 m^2 in a conifer forest of spruce, fir, and hemlock. The normal orange-red carpophores found in this area were comparable in every detail with Hypomyces lactifluorum growing abundantly throughout the same forest.

Fries (1821) validated Schweinitz's original description and defined the species as vermilion "--tenuis cinnabarina--", and there is no mention of a pallid or white color variant. Seaver (1910a,b) in two important papers on North American Hypocreales discussed only the normal orange-red form. Dr C. T. Rogerson, the present North American specialist for the Hypocreales (1970), did his doctoral dissertation on the genus Hypomyces (1950), and he did not report a white variant in H. lactifluorum. A recent paper by Hamlin (1963) which discussed the morphology of this species in detail does not mention color variants. The authors have collected in Nova Scotia for a total of 63 man-yr, and this is the first distinctive color variation found in this species. It is a rare form indeed.

RESULTS

All specimens from the group under discussion are placed in one collection, ACAD 11977, and are deposited in the E. C. Smith Herbarium, Acadia University. The parasitized mushrooms are infundibuliform with eccentric stipes, and can not be identified to species.

Eight carpophores were collected and the color variants are as follows: three entirely white specimens (10-12.5 x 10-12 cm), Figure 1; one white specimen with orange streaks (9.5 x 9.5 cm); one orange specimen with white streaks (12 x 10 cm), Figure 2; and three complete orange-red "normal" specimens measuring 8-12.5 x 7-12 cm, Figure 1. All the specimens produced ascospores that are 31 to 40(45) x 7 to 9(10) , hyaline, fusiform with acute apiculi, two-celled, verrucose, and slightly constricted at the septa. Other microscopic characters are in general agreement with Hanlin's published description (1963) excepting that no conidial stages were found. Macroscopic characters are in agreement with those published by Smith (1975).

DISCUSSION

Dr C. T. Rogerson was contacted and informs us that over the years he has received two single white specimens without adequate notes that had microscopic characters that fall within the ranges of H. lactifluorum. He did not report these because of lack of necessary details. It appears that careful search in other areas where this species occurs may yield additional material.

Our collection fortunately has specimens that are orange as well as white with the variegated intermediates which were all sporulating. The spores produced by the color variants were morphologically the same throughout the collection. Hanlin (1963) reported ascophores, 35 to 45 x 6 to 7.5 µm, that are smaller in width than those examined from our material; however, all other characters are the same. We are convinced that our specimens are H. lactifluorum, and show unexpected genetic color variants of the species. We feel that a new variety should not be established on a distinctive phenotypic expression of what may be a minor change in genotype.

ACKNOWLEDGEMENTS

We express our sincere appreciation to Dr Clark T. Rogerson, Curator, The New York Botanical Garden, Bronx, N. Y. for a personal communication, to Dr D. E. Stuntz, Department of Biology, University of Washington for a research of literature unavailable to us, and Dr Forrest Bent, Department of Biology, Acadia University for reviewing the manuscript. We are grateful to Mr Kenneth J. Harrison who prepared the half-tone photographs. Our research was supported by NRCC Grant A-2826.

REFERENCES

FRIES, E. M. 1823. Systema Mycologicum Vol. II. Lundae.

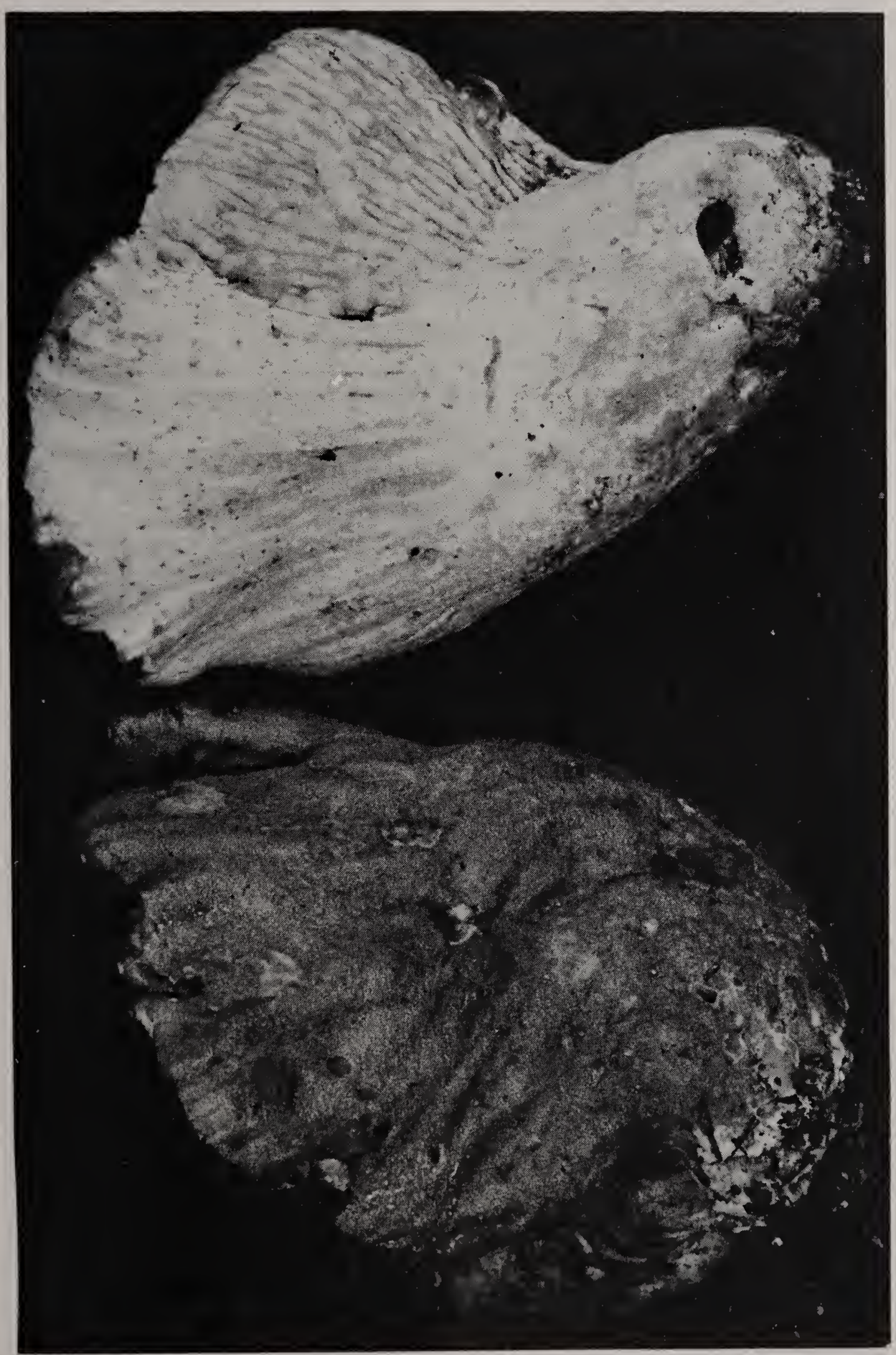

Fig 1. Hypomyces lactifluorum. Left, normal orange-red carpophore; right, albino variant. × 0.75.

Fig 2. Hypomyces lactifluorum. Left, white variant with orange-red streaks; right, orange-red variant (lightest orange at the normal color

HANLIN, R. T. 1963. Morphology of Hypomyces lactifluorum. Bot. Gaz. 124: 395-404.

ROGERSON, C. T. 1950. Studies in the Genus Hypomyces. Ph.D. Thesis, Cornell Univ., Ithaca, N.Y.

ROGERSON, C. T. 1970. The hypocrealean fungi (Ascomycetes, Hypocreales). Mycologia 62: 865-910.

SEAVER, F. J. 1910a. The Hypocreales of North America III. Mycologia 2: 48-92.

SEAVER, F. J. 1910b. Hypocreales. N. Am. Flora 3: 1-88.

SMITH, A. H. 1975 A Field Guide To Western Mushrooms. Univ. Michigan Press, Ann Arbor.

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STUMP SPROUT FORMATION BY RED MAPLE (*ACER RUBRUM* L.) IN NOVA SCOTIA

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During the autumn and winter of 1977, two mixed-wood forest areas near New Ross, Nova Scotia that had been heavily cut or clear cut and one in Kejimukujik National Park were examined for red maple (Acer rubrum L.) regeneration due to stump sprout development. It was established that the number of sprouts produced will be greatest around stumps 30 cm in diameter and 80 yrs old. Maximum elongation of sprouts (76 cm per annum) occurred around stumps with 30 sprouts, whilst above that number the rate of sprout elongation decreased. Sprout numbers decreased with increasing sprout age from a mean of initially 30 to 24 at 10 yrs, to 12 at 30 yrs and 3 at 75 yrs. This was considered to be the result of intraspecific competition (self-thinning).

INTRODUCTION

Information regarding stump-sprout formation in red maple has uses in wildlife management as sprouts are browse for deer and in timber management where fiber production and/or quality may be the primary concern. This study examines red maple sprouting to reveal the relationships between stump characteristics and the number and height of sprouts in Nova Scotia.

METHODS

Three areas, one near Armstrong Lake, Kings County, another near New Ross, Lunenburg County, and a third in Kejimukujik National Park, Queens County, were selected for study. The site located in Lunenburg County had been clearcut 1 yr ago whereas the Armstrong Lake site had been clearcut 5 and 7 yrs ago. The two areas were similar topographically, both consisting of undulating terrain with granite boulders at the surface and areas of swamp. The soils of the area are described by MacDougall and Cannard (1965). The regenerating species included balsam fir (Abies balsamea), white pine (Pinus strobus), and red maple, with red maple being the most abundant species. The area in Kejimukujik National Park was undulating with variable drainage and consisted of maple-oak-birch (Acer rubrum - Quercus rubra - Betula papyrifera) forest which had been cut about 40 yrs previously. The presence of

red maple was attributed to stump sprouting rather than the establishment of seedlings. Similar observations have been reported elsewhere, see for example Wilson's (1968) account of red maple in Harvard Forest (Massachusetts).

A total of 84 red maple stumps exhibiting sprout formation were selected. Of these, 12 came from the 1 yr old site, another 12 from data collected at Kejimukujik National Park (mostly 40 and 50 yr old) and the remainder were composed of variously aged (mostly 5,7, and 20 yr old) sprouts from the Armstrong Lake area.

Stumps which were sampled (excluding those from Kejimukujik National Park) were randomly selected and then assessed as to their suitability for enumeration. Suitable stumps were those which occurred singly and not in clusters and those which could be easily aged. It was thought that measurements made on stumps occurring in clusters would introduce a complication in data interpretation because of competitive interactions between sprouts on different stumps. Some stumps, especially those cut 5 and 7 yrs ago, had decomposed to such a degree that aging was difficult. Lower cut stumps were often covered with leaves which appeared to encourage decomposition.

Once a stump had been selected, several parameters were measured. Stump diameter was calculated from circumference measurements; stump vigor (last 10 yr radial increment) and basal area increment were recorded as well as sprout height and sprout diameter 10 cm up from the base of the sprout. Because clear cutting had been practised, the residual basal area of the stands were near zero.

Linear multiple regression and polynomial regression methods as available from the University of Manitoba's Computer Statistical Package were applied to the data in order to establish the relationships between the parameters involved. The equations selected gave the highest coefficients of correlation and the lowest standard deviation of estimate.

RESULTS and DISCUSSION

The number of red maple sprouts was related to the age of the stump (Fig 1) and its diameter (see Fig 2). The equation relating number of sprouts to age is based on 46 5-yr old sprouts and is:

Eq (1) $$y = 2.414 + 0.006x^{3/2} - .0005x^{2}$$

where y is the natural log of the number of sprouts plus one, and x is the stump age in yrs. This equation is significant at the 1% level and has a coefficient of correlation of 0.855 and a standard deviation of the estimate of 0.229.

Equation 1 is shown in Figure 1 and indicates an age class (65-95 yrs) that produces more sprouts than younger (<65 yrs) or older stumps (>95 yr old). The increase in number of sprouts may be attributed to increasing surface area and increased resources up to 65 yrs of age with a decrease resulting from reduced stump vigor as the stumps become older. Thus, with decreasing vigor fewer sprouts were produced.

The equation relating the number of sprouts to stump diameter is based on 46 5-yr old sprouts and is expressed:

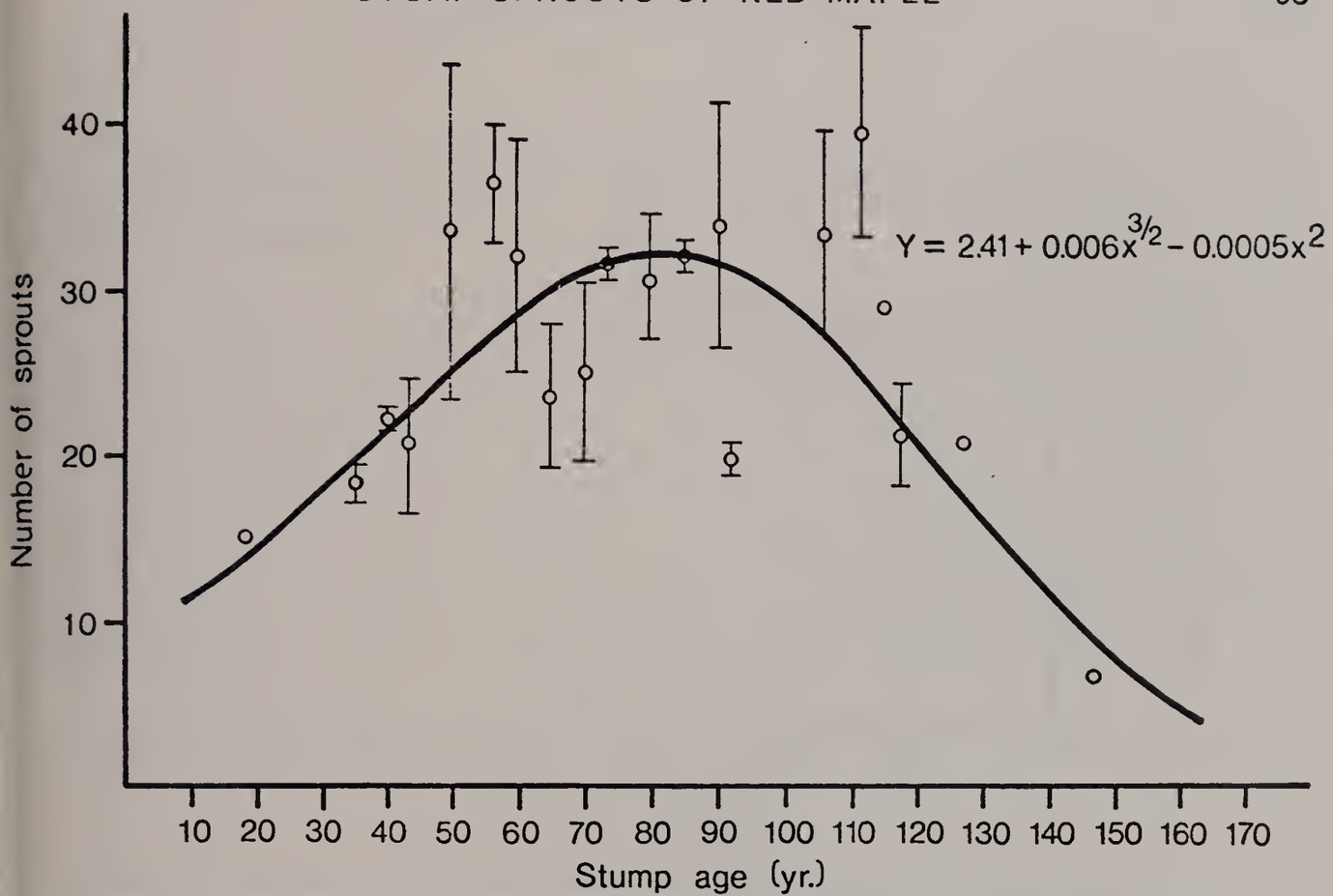

Fig 1. Relationship between number of sprouts and stump age; vertical line indicates one standard deviation and Y = log (no. of sprouts + 1).

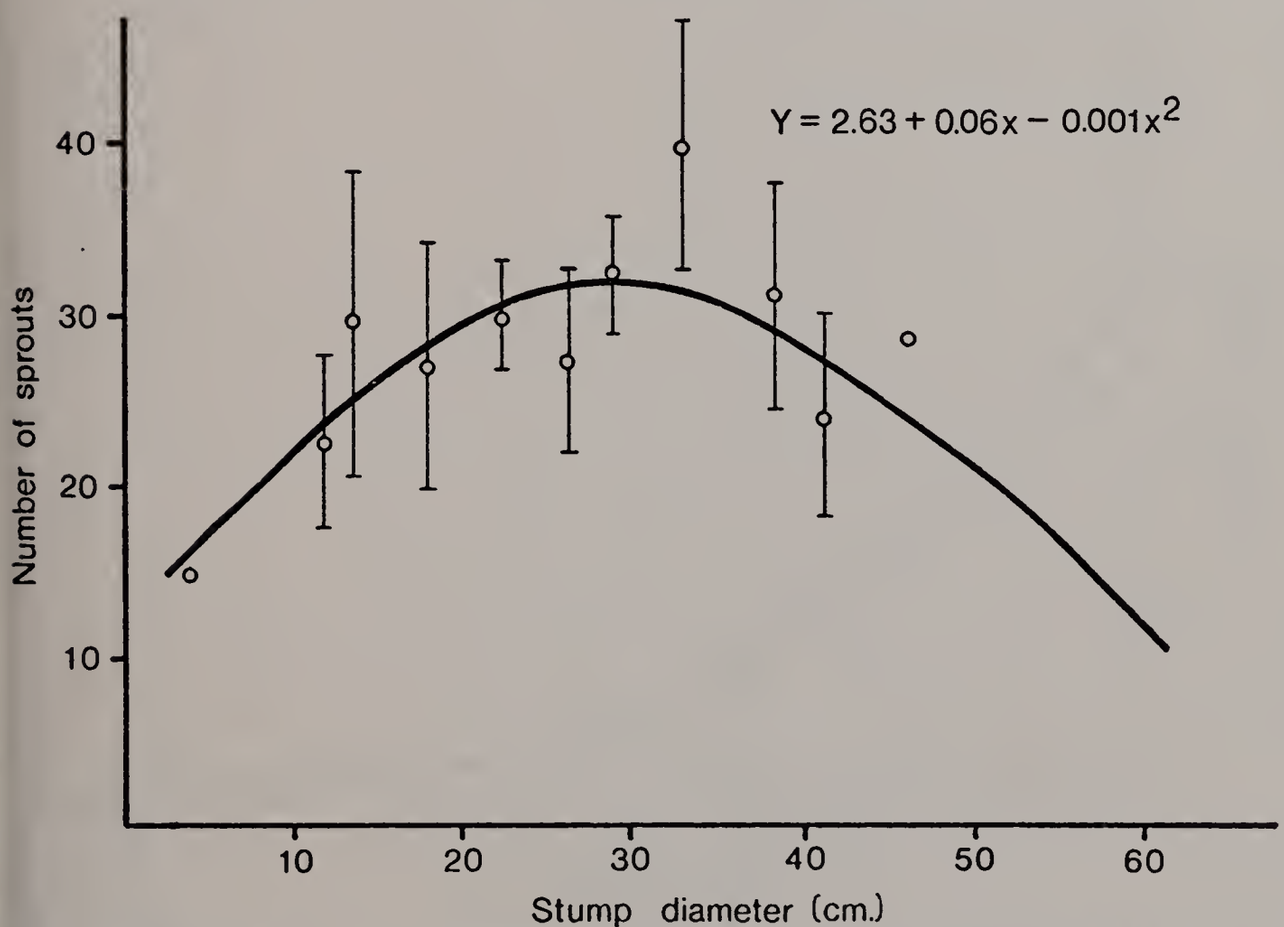

Fig 2. Relationship between number of sprouts and stump diameter for red maple; vertical line indicates one standard deviation and Y = log (no. of sprouts + 1).

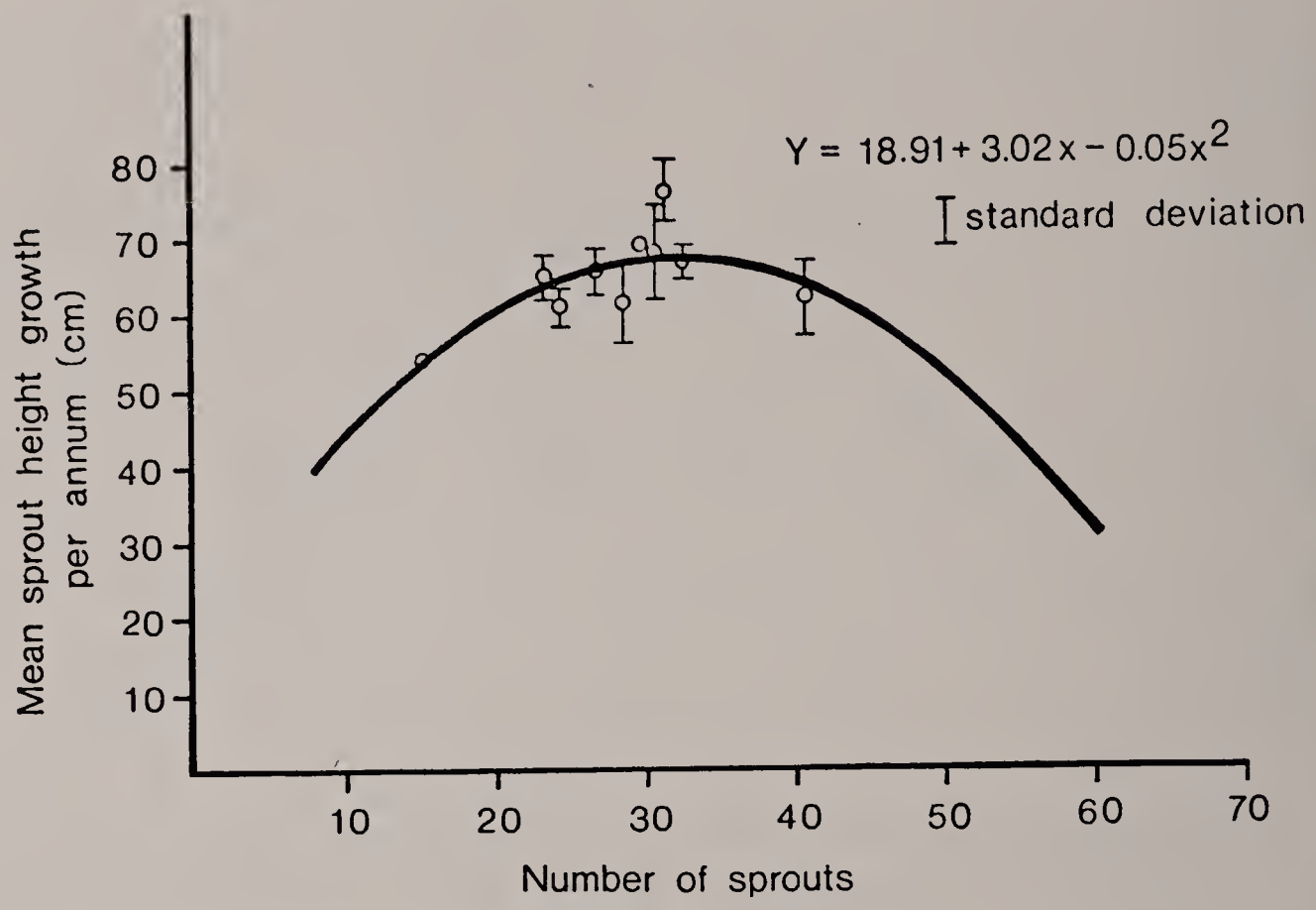

Fig 3. Relationship between sprout height elongation and sprout numbers; the points represent diameter classes at 5 cm intervals.

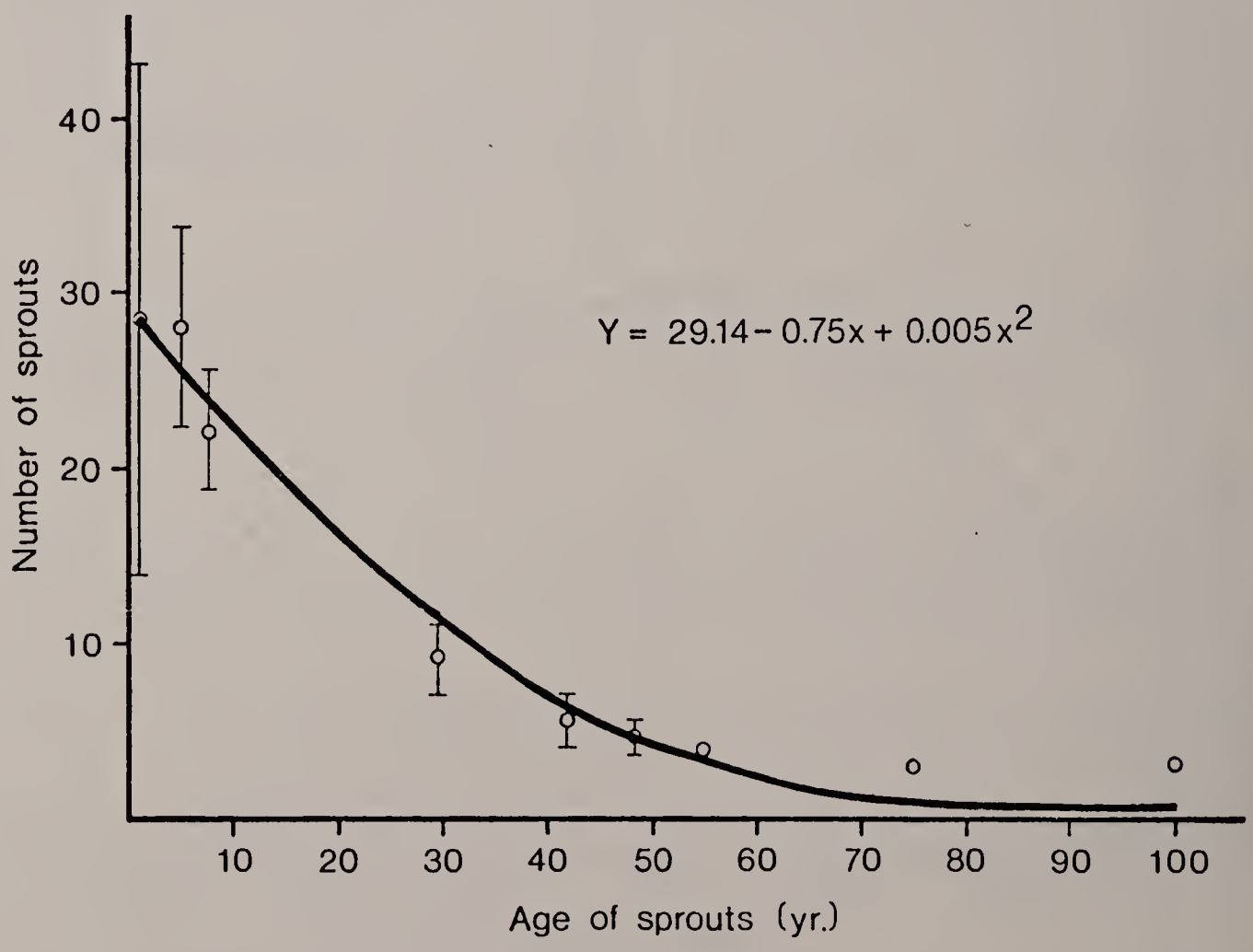

Fig 4. Self-thinning curve for red maple stump sprouts; vertical line indicates one standard deviation.

Eq (2) $y = 2.629 + 0.059x - 0.001x^2$

where y is the natural log of the number of sprouts plus 1, and x is the stump diameter in cm. This equation is significant at the 1% level, the coefficient of correlation is 0.855, and the standard deviation of the estimate is 0.142.

Equation 2 is shown in Figure 2 and demonstrates an initial increase (up to 30 cm) and subsequent decrease in sprout numbers with increasing stump diameter. The trend is consistent with, but higher than the observations of Solomon and Blum (1967) who noted that stump sprouting was most prolific in the 15 to 30 cm range.

With increasing stump diameter there is an increase in the resources available for sprout development. Because of this 'reservoir' it is probable that it encourages an increase in sprout numbers. In Figure 2 we can attribute the decline in the number of sprouts, after the diameter exceeds 30 cm, to the lower vigor of older stumps (see Fig 1) since stump diameter generally increased with age.

The relationship between sprout elongation and numbers is based on 46 5-yr old sprouts and can be written:

Eq (3) $y = 18.915 + 3.016x - 0.047x^2$

where y is sprout elongation and x is the number of sprouts. The equation is significant at the 5% level, with a coefficent of correlation of 0.81 and a standard deviation of estimate of 3.672. Some polynomial equations having a higher coefficient of correlation were rejected because, when plotted, graphs were produced that depicted relationships that were intuitively incorrect (ie, with multiple kinks or repeatedly falling below the x axis). The plotted equation (Fig 3) exhibits an interesting relationship between sprout elongation and increasing sprout numbers. The graph that might have been expected would have been one that had a "y" intercept at some value above 70 (see Fig 3) and a line that gradually decreased with increasing sprout numbers. This would have resulted from increased sprout numbers causing an increase in the degree of competition (the amount of nutrients and space/light become less). Such a relationship, however, we would expect with any stump diameter. In Figure 3 the stump diameters vary as well as stump ages and both are influencing the result. From Figure 2 it is evident that initially an increase in the number of sprouts is associated with an increase in stump diameter. Thus in Figure 3 an increase in sprout numbers, up to about 30 sprouts, is also reflecting an increase in stump diameter (which may be thought of as an increase in the resources available). Therefore, with increasing resources there is an increase in sprout elongation. Since competition is playing a part, we might say that the small elongation for the small number of sprouts results from two components: (1) competition between sprouts and (2) the small initial supply of resources. In Figure 3 initially the latter component is the more important. However, the number of sprouts decreases as age increases (corresponding to an increase in stump diameter). At the same time the component for competition between sprouts is increasing and continues to increase as more sprouts are added. In other words, as the resources available

for sprout formation and growth increase and reach their maximum, the competitive interactions between sprouts become increasingly more important as the major influence on sprout elongation.

The equation relating sprout age and number of sprouts is:

Eq (4) $$y = 29.14 - 0.75x + 0.005x^2$$

where y is the number of sprouts and x is the sprout age in yrs. The equation is significant at the 1% level and has a coefficient of correlation of 0.988 and and a standard deviation of estimate of 1.997. Figure 4 shows quite distinctly the effect of competition on the number of sprouts. As sprouts become older and larger, the number of sprouts decreases.

Initially, because of the great variability within all measurements, the relationship between the parameters was unclear. In order to reduce the amount of variability, values that were being plotted on the x-axis were grouped into classes from which means and standard deviations were calculated. The mean values were then used to determine the equations which were then plotted as were the calculated mean values. With each mean value the standard deviation about that point was plotted and this should be taken into consideration when interpreting the graphs (eg, one standard deviation implies a probability of approximately 0.68 that any point in that class is to fall on the indicated margin.)

The relationships which were obtained were the only ones that could be shown significant at the 5% level (or less). Relationships which could not be established were those between numbers of sprouts or sprout height and 10 yr basal increment (in cm^2) or mean 10 yr radial increment.

CONCLUSIONS

This preliminary study indicates trends and features of sprout formation from red maple stumps. Equations 1 to 4 have potential for manipulating the regeneration of red maple. If an area is to be managed for timber production, then in order to produce suitable maple trees the large number of sprouts may have to be reduced. Equation 3 suggests that in order to maintain the maximum growth in height, elimination of all sprouts but one (to reduce competition) may not be the answer. Thus, the optimum method of maximizing sprout height would be to harvest some sprouts each year. The numbers of sprouts removed would be a function of the number present, stump diameter and age and the number of years since the stump had been cut. If harvesting is to be carried out with the intention of increasing future yields of red maple, then trees that are in the diameter class 20 to 24 cm and the age class 65 to 95 yrs would produce more fiber (as new sprouts) than other stump diameter and age classes.

If the primary management objective is concerned with providing food for deer, then the trees that should be cut would be those that did not produce fast growing sprouts since such sprouts would soon be beyond the reach of the deer. Thus, sprouting features to be maximized are (1) large numbers of sprouts with (2) smaller height increase per year.

REFERENCES

MACDOUGALL, J.I. and CANNARD, D.B. 1965. Soils Survey of Kings Co., Nova Scotia. Can. Agr. Marketing, Report no. 15, 97 pp.

SOLOMON, D.S. and BLUM, B.M. 1967. Stump sprouting of four northern hardwoods. U. S. Forest Res., Paper NE-59, 16 pp.

WILSON, B.F. 1968. Red maple stump sprouts: Development the first year. Harvard Forest Paper 18: 1-10

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EVIDENCE AGAINST AUTOGAMY IN *VACCINIUM ULIGINOSUM* L.

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Controlled selfs on four tetraploid (2n=48) and 5 diploid (2n=24) plants of Vaccinium uliginosum L. were unsuccessful. These negative data were supported by field observations from Halifax Co., N.S. where a single tetraploid clone interbreeds with Vaccinium angustifolium Aiton.

INTRODUCTION

Both Warming (1908) and Hagerup (1933) reported that in Greenland Vaccinium uliginosum L. forma microphylla Lange was largely self-pollinating and by inference self-compatible. Apogamy was dismissed since stigmata were encrusted with pollen grains and pollen tubes were actively growing in the style. Hagerup (1933) averred that an outbreeding system would be selected against since insects were scarce in the Arctic. An observation challenged by Kevan (1972) who found ample insect activity in the high Canadian Arctic. Moreover Ballington (1975) and Vander Kloet (1976) have independently shown that interflower selfing is largely unsuccessful in experimental populations of several species of Vaccinium ξ Cyanococcus and in one of them, V. angustifolium Aiton is a complete failure (Vander Kloet 1976). The purpose of this paper is to show from experimental and field data that V. uliginosum does not self.

MATERIALS and METHODS

In the autumn from 1973 until 1976, 20 small populations (2-15 plants) were started from seed taken from open pollinated berries collected at 17 sites scattered throughout eastern North America between 44°N and 75°N. Vouchers are in the E.C. Smith Herbarium, Acadia University at Wolfville, N.S.

Seedlings were kept in the greenhouse until perennating buds had formed; they were then transferred to a coldframe until the following April when they were returned to the greenhouse, which was kept insect free and at 20°C during the day and 10°C at night, and where they began to flower after 5 wk. Once blooming began, plants in flower were isolated and from each, 10 stigmata were excised at random and examined for the presence of pollen grains. In addition pollen was removed from several flowers, imbedded in a drop of 10% sucrose in a 0.7% agar solution, in order to follow pollen tube growth and thereby assess pollen viability. After the corolla of undisturbed flowers had dropped, the development of the calyx was observed. Finally one or two plants from each flowering population were selfed.

RESULTS and DISCUSSION

Of the 70 plants under cultivation in 1976, 18 have flowered and of these 4 were tetraploid 2n=48, the remainder diploid 2n=24 (Fig 1). Annually these 18 plants produced at least one flower and often more than 80, but regardless of flower density, none set seed and the last calyx usually dropped in mid-June, undeveloped. Twenty seven of the 30 stigmata excised at random from the corollas had no pollen encrusted in them; the remaining three stigmata contained 1, 4, and 7 grains

Fig 1. Comparison of progeny out of #11873 with a tetraploid plant from St. Anthony, Newfoundland 127874, and a diploid plant from West St. Modeste, Labrador 735.

respectively. Pollen collected from 7 plants had 35±16% germination; although pollen viability was not high, many of the tetrads had more than one pollen tube. Moreover selfing failed on the 9 plants attempted. In 1974, interplant crossing among homoploids was successful.

These negative experimental results discount autogamy and agree well with observational data on the species in Nova Scotia obtained from 1972 until the present. In October 1972, I discovered a single clone of V. uliginosum on the headlands of Portuguese Cove, Halifax Co., N.S. which was the first collection of this species on the Nova Scotia mainland. Repeated and lengthy searches of adjacent headlands in the following years yielded no additional colonies. This clone is well established, 5 m in diameter with a small tree of Picea glauca in the center of the clone. About 5 or 6 berries are produced on the entire clone although it has flowered quite abundantly each year (up to 35 flowers per shoot). The berries collected so far contained 5±3 seeds which germinated quite readily when fresh in 1973 and 1976 but not in 1975. In 1974 fruit was not collected.

The progeny produced from these few seeds does not resemble its female parent, nor any plant of V. uliginosum (Fig 2). The leaf blade is elliptic rather than ovate; the margin is obscurely serrate, each serration being tipped with a gland, as well as a few hairs (see Fig 2). All these characters suggest hybridization with V. angustifolium; it would, therefore, be an intersectional hybrid, a condition not entirely unknown in Vaccinium. Ritchie (1954, 1955) has shown that the European V. intermedium Ruthe is a hybrid produced by V. myrtillus L. and V. vitis-idaea L.

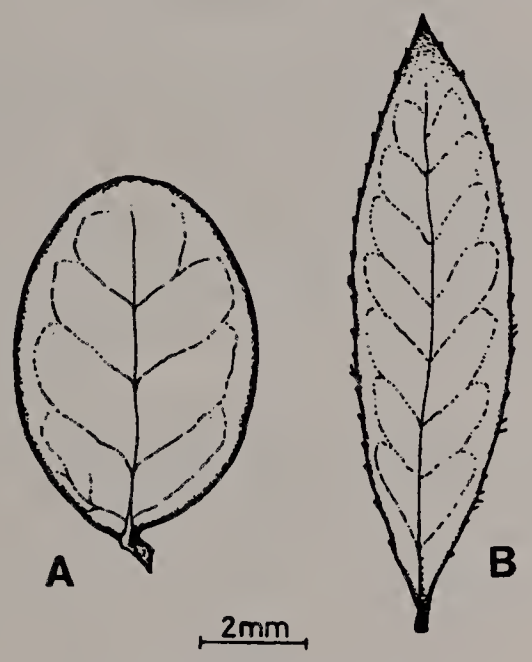

Fig 2. Comparison of leaf shape, venation pattern, and margin of the female parent 11873 (A) to one of its progeny (B).

Moreover, the potential for V. uliginosum to cross with V. angustifolium at Portuguese Cove is quite high; both are tetraploids and on 9 June 1977, both the single colony of V. uliginosum and V. angustifolium were in full bloom and being pollinated apparently indiscriminately by Bombus bimaculatus. Vaccinium vitis-idaea is also present on these headlands but was not yet in flower, and moreover is a diploid and therefore not likely to cross with this colony of V. uliginosum. Therefore, by elimination, V. angustifolium is the probable parent for these

experimental hybrids. Although I have yet to find the hybrid in the field, these field data do however support the experimental data and suggest that autogamy does not occur in V. uliginosum.

REFERENCES

BALLINGTON, J.R., Jr. 1975. The Breeding Biology of the Purported Diploid Ancestors of Vaccinium ashei Reade. Ph.D. thesis, North Carolina State Univ. at Raleigh, Raleigh, N.C.

HAGERUP, O. 1933. Studies on polyploid ecotypes in Vaccinium uliginosum L. Hereditas, 18:122-28.

KEVAN, P.G. 1972. Insect pollination of high Arctic flowers. J. Ecol. 60:831-47.

RITCHIE, J.C. 1954. An Investigation of Natural Hybridization in Vaccinium myrtillus L. and V. vitis-idaea L. Ph.D. thesis, Univ. Sheffield, Sheffield, U.K.

RITCHIE, J.C. 1955. A natural hybrid in Vaccinium. I. The structure, performance and chorology of the cross Vaccinium intermedium Ruthe. New Phytol. 54:49-53.

VANDER KLOET, S.P. 1976. A novel approach to sampling Vaccinium populations. Can. J. Bot. 54:669-71.

WARMING, E. 1908. The structure and biology of Arctic flowering plants. I. Ericineae. I. Morphology and biology. Medd. Groen. 36:1-71.

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CONTRIBUTION TO THE PAPUASIAN FLORA: NOTES ON THE ECOLOGY AND TAXONOMY OF THE VACCINIOIDEAE OF THE BULLDOG ROAD, MOROBE DISTRICT PAPUA NEW GUINEA

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Twenty one species of Vaccinioideae, including two new species, were collected at 10 sites along the Bulldog Road, Papua New Guinea. The highest species diversity and abundance occurred above 2600 msm, an altitude which coincides with the beginning of the cloud forest in this area. Dimorphanthera was the most ubiquitous and abundant genus whilst Vaccinium was quite rare. One new species, Vaccinium morobense, is described.

INTRODUCTION

The Hebert Expedition in 1975 towards Mt. Kumbak, Morobe Province, Papua New Guinea afforded me an opportunity to observe and describe the distribution of Vaccinioideae from Wau (1800 msm) to Edie Creek (2250 msm) and thence along the Bulldog Road to the height of land (3010 msm). This Road was constructed during World War II by Australian Troops who, on completion, promptly abandoned it; it was scarcely ever used by vehicles and is now destroyed by erosion, being overgrown in many places.

In North America such disturbed ground, provided the substrate is acid, is usually invaded by Vaccinium and other ericaceous genera (Camp 1942, 1945). Moreover, it is the species which are established in natural, undisturbed habitats in the area that occupy this disturbed ground. Hall (1959) found that in blueberry fields developed from woodlots, Vaccinium myrtilloides Michx. had the highest frequency of abundance since it tolerates shade and therefore persists in second growth forests, whilst in blueberry fields developed from abandoned meadows, V. angustifolium Ait. was more prevalent.

Likewise Sleumer (1965) observed the invasion of Rhododendron and Vaccinium on disturbed ground including the gold mine tailings at Edie Creek; he noted that the epiphytic Vaccinioideae may become terrestrial at the forest borders and at higher altitudes (Sleumer 1967). If the Vaccinioideae are as intolerant of shade as Camp (1942) has argued, the persistence of the group in the primary montane forests is impossible unless the several species have the epiphytic habit as part of their adaptive strategy, or else the species are restricted to subalpine shrubberies (or become part of the transitional assemblages which migrate from landslip to landslip, or else become ruderal).

METHODS

My objective was to carefully search at regular intervals a disturbed section of the Bulldog track and its adjoining primary forests especially for epiphytic Vaccinioideae - a task carried out during August 1975 when I systematically searched for Vaccinioideae along a 20 km section of this track, going from an elevation of 2000 msm (07°33'S/146°41'E) to the height of land at 3010 msm, with sampling points every 2 km. Vouchers have been deposited at LAE*, A, and ACAD. Types are at A.

RESULTS and DISCUSSION

Twenty one species of Vaccinioideae representing 5 genera were collected at the 10 sites. The highest species diversity and abundance occurred above 2600 msm (Table 1), an altitude which coincides with the beginning of the cloud or moss forest in this area. At the height of land (3010 msm) 2 small outcroppings were present which did not seem to be fire-induced barrens and on which only Vaccinium amblyandrum F.V.M. and V. finisterrae Schltr. were present; the bulk of the vegetation was Bryophyta and Epacridaceae.

Two species, V. molle J.J.S. and V. horizontale Sleumer, were exclusively found on disturbed ground, especially on the gold mine tailings at Edie Creek, ie they were behaving as Nomads (sensu van Steenis 1958). Vaccinium acrobracteatum K. Sch. was a strict epiphyte in the lower montane forests, but Brass (1941 p. 307, as V. adenantherum) has reported this species on sand at the mouth of the Bele Valley. Diplycosia morobeënsis Sleumer is also strongly epiphytic; only once at 2850 msm along the margin of the cloud forest did I see it as a weak terrestrial shrub.

The remaining species were not only present in transitional communities and disturbed sites such as dead fall, stumps, hedges, and edges, but were also members of more stable communities. Within the thickest primary moss forests from 2650 to 2850 msm, Vaccinium finisterrae Schltr., Agapetes brassii Sleumer, and Diplycosia morobeënsis Sleumer were epiphytic; Dimorphanthera denticulifera Sleumer was a scrambling or weakly erect understory shrub; Vaccinium carneolum Sleumer was an understory tree at 2850 msm in these moss forests.

Dimorphanthera is the most ubiquitous and abundant genus in the dense ericaceous shrubberies that occur along the track above 2600 msm as well as in glades and ravines whilst Vaccinium is quite rare in the Rhododendron shrubberies which occur on the outcroppings, mass wastage slopes, and track verges above 2650 msm. Gaultheria pullei J.J.S. is common in these Rhododendron shrubberies.

All these species of Vaccinioideae were in flower during August, but pollinators were scarce. Vaccinium molle J.J.S. was visited by Apis spp and corollas of Dimorphanthera ingens (Sleumer) Stevens and Vaccinium carneolum Sleumer contained weevils and thrips but whether these actually pollinate is a moot point. Kevan (1972) presents evidence from the Canadian high Arctic that they do. Birds and moths are probably important pollinators of Rhododendron spp (Stevens 1976), but the evidence for the Vaccinioideae is largely circumstantial. Species from three

*acronyms from Index Herbariorum, Holmgren & Keuken (1974).

Table 1. Elevational distribution and flower color of Vaccinoideae along the Bulldog track, PNG. 1st column (abundance): + rare; 1 occasional; 2 common; 3 abundant. 2nd column (flower density): + flowers sporadically; 1∞ small flowers (<10 mm); 2∞ large flowers (>10 mm); 3 masses of bloom.

Taxa	Flower color	Sample point 1	2	3	4	5	6	7	8	9	10
Vaccinium molle	cream		2,1	+,1	+,+	+,1	+,+	+,+	+,+		
V. horizontale	red		1,+			+,+					
V. cyclopense	red	+,+	+,+								
V. reticulato-venosum	red	+,+									
V. amblyandrum	white					+,+	3,+	2,+	2,+	3,1	3,+
V. finisterrae	red						2,+		+,+	2,+	+,+
V. myrsinoides	red					+,+	1,+		+,+	+,+	
V. carneolum	red						2,2	2,+	+,2	2,2	+,2
V. morobense	red					+,+	+,+				
V. acrobracteatum	red			+,+	+,+	+,+	+,+	+,+	+,+		
Dimorphanthera anchorifera	red	+,+	2,+								
D. denticulifera	red						2,2	+,2	1,2	+,+	
D. amplifolia	red	+,+	+,2				+,2	+,2	+,2	2,2	
D. calodon	red					+,2	1,3	+,2	+,2	1,2	
D. ingens	white					+,+	+,+	3,3	1,2	1,2	
D. albida	white							+,2	2,3	2,3	
Agapetes brassii	yellow-red							+,+	1,2	2,2	1,2
A. vitis-idaea	yellow-red							+,+	+,+	1,2	
A. prostrata	yellow-red							+,+			
Diplycosia morobeënsis	white			+,+	+,+	+,+	+,+	+,+	+,+	+,+	+,+
Gaultheria pullei	white						3,3	+,+	1,1	+,+	
	m s m	2250				2600			2750		3000

sections of Dimorphanthera are known to be visited by birds (see Sleumer 1967; Stevens 1976, 1977; also D. calodon Sleumer, below). The predominant flower color of these Vaccinioideae is red which according to Kevan (1972) is insect yellow, orange, or black. Only where Dimorphanthera albida Stevens and D. ingens (Sleumer) Stevens were massed did white stand out.

In short, most of the Vaccinioideae that occur along the Bulldog track have populations in more stable communities which are not necessarily adjacent to the ruderal populations. Frequency of occurrence is, however, quite low in the primary moss forests as compared to numbers along the track. Dimorphanthera is a notable exception to this trend; it is both abundant in glades and along the track at 2850 msm. The Vaccinioideae are, therefore, just as opportunistic in Papua New Guinea as they are in North America with the notable exception that several species can retreat (or migrate) into the trees ie become epiphytic rather than face local extinction in the encroaching primary moss forests.

SYSTEMATIC LIST

1) Vaccinium molle J.J. Smith.

Erect, crown-forming, terrestrial shrub 0.3-5 m high, common on gold mine tailings (pH 4.5-5.1, organic content <10%) and outcroppings at Edie Creek; rare but ubiquitous on disturbed ground elsewhere on the track, but absent from the highest elevations. Seedlings were observed among clumps of grass and in Lycopodium mats. Although the species was still flowering, the first ripe berries of the current season were collected in late August. The pale yellow pubescent berries contained many small pale brown seeds (8 mg/100 seeds), which germinated quickly in 12 to 14 d but were extremely susceptible to damping off.

2) Vaccinium cyclopense J.J. Smith.

Trailing shrub found twice in moss carpets on roadside cliffs near Edie Creek; absent elsewhere. Flowering during August but fruiting sparsely; berry mauve, containing many small brown seeds (12 mg/100 seeds) which germinated readily in 25 to 30 d, but seedlings were very susceptible to damping off.

3) Vaccinium horizontale Sleumer.

Erect, crown-forming, terrestrial shrub 2 to 3 m high, very rare, only 3 plants seen on gold mine tailings at Edie Creek and one along the track at 2500 msm. Fruiting and flowering simultaneously during August. Berries black, somewhat shiny, 1 cm in diameter, and quite astringent; each berry contained 1 to 7 large seeds which germinated readily in 30 to 40 d.

4) Vaccinium reticulato-venosum Sleumer.

Scandent, scrambling, partially erect shrub 2 to 3 m high, margin of Nothofagus forest, Mt. Kaindi, Edie Creek Road; very rare.

5) Vaccinium amblyandrum F.V. Mueller.

Erect, creeping, or scrambling terrestrial shrub (3)30 to 50(90) cm high, rhizomes sometimes superficial then forming extensive creeping

mats, sometimes the rhizomes are subterranean then the plant forms extensive colonies; occasionally caespitose and scrambling especially on rotting tree stumps. Locally abundant above 2600 msm especially on outcroppings and slip slopes; massed along both sides of the track above 2800 msm; occasionally it occurs in open Rhododendron shrubberies. Soil often coarse and water logged (pH 4.1-5.0; organic content <12%). This species flowered sporadically throughout August, but no ripe fruit was observed.

6) Vaccinium finisterrae Schltr.
Slender erect, or scrambling terrestrial, or rarely an epiphytic shrub, 30 to 100 cm high. Occasional from 2600 msm to the height of land in a variety of habitats, viz an epiphyte in moss forests, along the margin of the track where it is associated with Vaccinium amblyandrum; an understory shrub in Rhododendron shrubbery; on exposed slip slopes and outcroppings. This species was in full flower during August; no ripe fruit was observed.

7) Vaccinium myrsinoides Schltr.
Erect terrestrial shrub 60 to 250 cm high, usually quite rare and seen only between 2600 and 2850 msm where it occurred along the margin of the track and rims of mass wastage slopes. This species was also flowering profusely during August but fruiting sparsely; berries dull and black, containing ca 6 small seeds which germinated after 40 d.

8) Vaccinium carneolum Sleumer.
Small tree or erect crown-forming terrestrial shrub 1.5 to 5 m high, common to occasional in disturbed habitats or as an understorey tree in the moss forests from 2650 msm to the height of land; in flower during August, ripe fruit absent.

9) Vaccinium morobense Vander Kloet sp nov (Fig 1, 2).
A speciebus aliis Vaccinii Malesianae in folia obovata usque ad 2 cm longo margine integra, pilis multicellularibus glandulosis subcapititis, inflorescentia axillari cum 2 ad 5 floribus, axe usque ad 12 mm longo floribus versus apicem ortis, bracteae deciduae, ovario pseudo 10-loculare, flore urceolato, filamentis pilosis, et antheris pilis multicellularibus glandulosis praeditis, differt.

Frutex usque ad 1.5 m altus. Ramulus juventute circa 0.8 mm in transverso, angulatus (angulis e basibus petiolorum decurrentibus), pilis unicellularibus curvatis et multicellularibus glandulosis subcapitatis praeditus; perulae gemmarum late ovatae, 0.6 and 0.8 mm longae. Petiolus 1.5 ad 2 mm longus; lamina obovata 1.2 ad 1.9 cm longa et 0.45 ad 0.8 mm lata, apice rotundata, basi cuneata, margine integra recurvata prope basem glandulis duabus instructa, supra pilis unicellularibus super costam pilis multicellularibus super et prope costam praedita, infra pilis paucis multicellularibus pagina tota praedita, costa supra leviter elevata vel depressa infra leviter elevata, nervis lateralibus pari uno prope basem ortis, nervis aliis parvioribus supra obscuris vel planis infra planis. Inflorescentiae subcorymbosae, floribus 2 ad 5 versus apicem axis ortis, axibus 2 ad 12 mm longis pilis (perpaucis) multicellularibus et interdum unicellularibus praeditae; bracteae mos deciduae, oblongo-ovatae, circa 2.5 mm longae; pedicelli 5-8 mm longi cum calycibus articulati,

Fig 1. Scanning electron micrograph of a pollen tetrad from Vaccinium morobense sp nov (Vander Kloet 164875).

pilis multicellularibus praesertim versus apices praediti, bracteolis haud cognitis. Tubus calycis 1.5 ad 1.9 mm longus versus basem pilis multicellularibus praeditus, lobis 5 triangularibus 0.9 ad 1.4 mm longis fissus marginibus haud glanduliferis apicibus cirris pilorum unicellulorum praeditis; corolla urceolata testaceo-rubra vel rubra (lobis albis) circa 7 mm longa et 4.5 mm lata (ad orem circa 2.5 mm lata), extus glaber intus pilis unicellularibus prope basem excepta praedita, ad orem papillata, lobis 5 triangularibus circa 0.6 mm longis fissa; stamina 10, ecalcarata, filamentis 2.5 ad 2.8 mm longis pilis densis unicellularibus praeditis, antheris thecis 1.6 ad 2 mm longis, papillatis, basibus rotundatis, tubulis quam thecis leviter angustioribus circa 0.8 mm longis, laevibus, sed pilis multicellularibus glandulosis versus apices praeditis, poris subobliquis terminatis; ovarium inferum pseudo 10-loculare; discus glaber; stylus circa 5.5 mm longus, glaber, tumidus, prope apicem angustatum, stigmate leviter expanso. Fructus immaturus circa 4.7 mm longus et 4.3 mm latus.

Type: Papua New Guinea, Morobe District, Wau Region, Bulldog Road, 2600 msm, Aug. 1975, Vander Kloet 164875 (holotype, A).

Distribution: Morobe Province, Papua New Guinea.

Additional specimen seen: Papua New Guinea. Morobe, Bulldog Road, 2500 msm, Vander Kloet 36875(A).

Ecology: Vaccinium morobense is sometimes a clump forming shrub growing on steeply sloping ground or old tree stumps in montane forest, often growing with other Ericaceae. Flowering specimens have been collected in August.

Vaccinium morobense can readily be distinguished from other species of the genus by its small, obovate leaf blades, its indumentum of crisped unicellular and small, stalked, subcapitate glandular hairs, its few-flowered, subcorymbose inflorescence, deciduous bracts, falsely 10-locular ovary, densely pilose filaments and ecalcarate anthers with multicellular, eglandular hairs.

Like other Malesian-Southeast Asian species of the genus, Vaccinium morobense has a superficial phellogen (Vander Kloet 164875), but it is

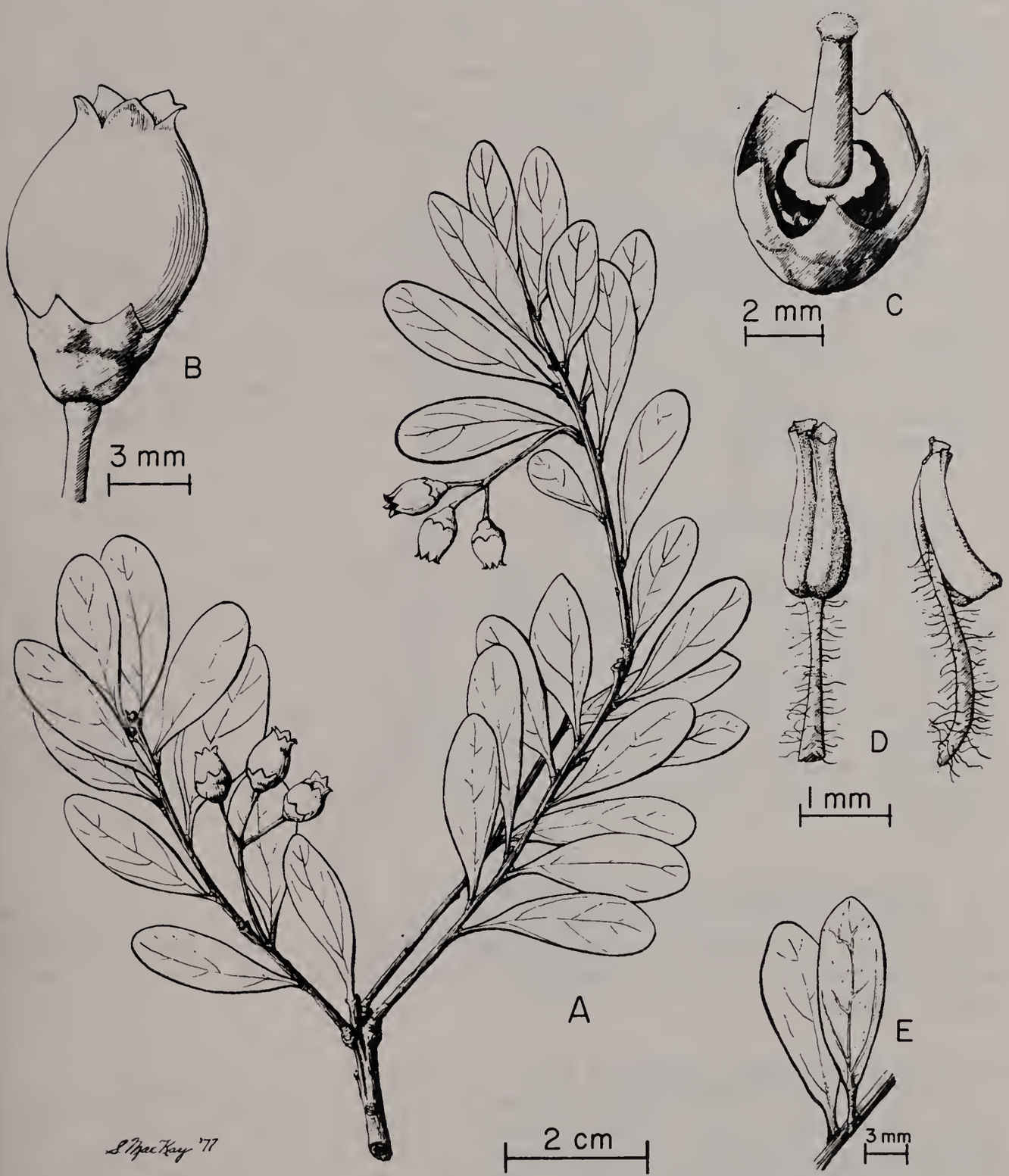


Fig 2. Vaccinium morobense sp nov (A) habit (Vander Kloet 36875); (B) flower; (C) ovary, disk and style; (D) stamens; (E) leaves (Vander Kloet 164875).

difficult to assign it to a section. In general facies it is very like the microphyllous species placed in ξ Oarianthe Sleumer, but it differs in its inflorescence, which has a distinct axis and bears 2 to 5 flowers. Members of ξ Oarianthe sometimes have a very short inflorescence asix, but there is only a single flower. In addition, glandular hairs on the anthers appear to be unknown in ξ Oarianthe (Sleumer 1967), although they may have been overlooked. Vaccinium morobense is provisionally included in ξ Bractaeta Nakai in which the inflorescences have well developed axes; a number of Malesian species in this section have anthers with glandular hairs or points. Vaccinium morobense keys out as V. longiporum in Sleumer (1967), but may readily be separated from that species on lamina shape and size (obovate, rounded at the apex, and less than 2 cm long in V. morobense; elliptic (lanceolate) caudate, acuminate at the apex, and at least 5 cm long in V. longiporum) and inflorescence size (2-5 flowers vs 5-10 flowers).

10) Vaccinium acrobracteatum K. Schumann.

Erect or scrambling epiphytic shrub 2 to 5 m high, occasional in crotches of massive Nothofagus and Lithocarpus trees from 2400 to 2800 msm. Some of these crotches contained more than 50 cm^3 of peaty material. Shrubs were either flowering or fruiting during August. Berries purple to black, 4 to 8 mm in diameter; many seeds (22 mg/100 seeds) few of which germinated after 25 to 35 d; seedlings stout, main axis has a "zig-zag" growth pattern; both young leaves and stem densely glandular (Fig 3).

11) Dimorphanthera anchorifera J.J. Smith (including D. brassii Sleumer).

Scandent, scrambling or arching terrestrial shrub 1 to 3 m high, common in the Edie Creek area along forest edges, rotting tree trunks, on dead fall, and along woodlot margins. Not seen elsewhere. Flowering and fruiting sparsely in August: berries purple, 10 to 14 mm in diameter; outer layer tough, 2 mm thick, neatly incised by birds which remove sap and seeds. These seeds are quite small (7 mg/100 seeds), triangular, and are almost fused together within the locule; fresh seeds germinate readily after 20 to 30 d; seedlings prostrate, stem develops in a zig-zag pattern, young leaves becoming cordate and densely glandular (Fig 4).

12) Dimorphanthera denticulifera Sleumer.

Weakly erect or scrambling terrestrial shrub 3 to 5 m high, stems up to 10 cm in diameter, common from 2600 msm to 2850 msm in ericaceous shrubberies or as an understory shrub in the moss forests. Flowers during August.

13) Dimorphanthera amplifolia (F.v.M.) Stevens.

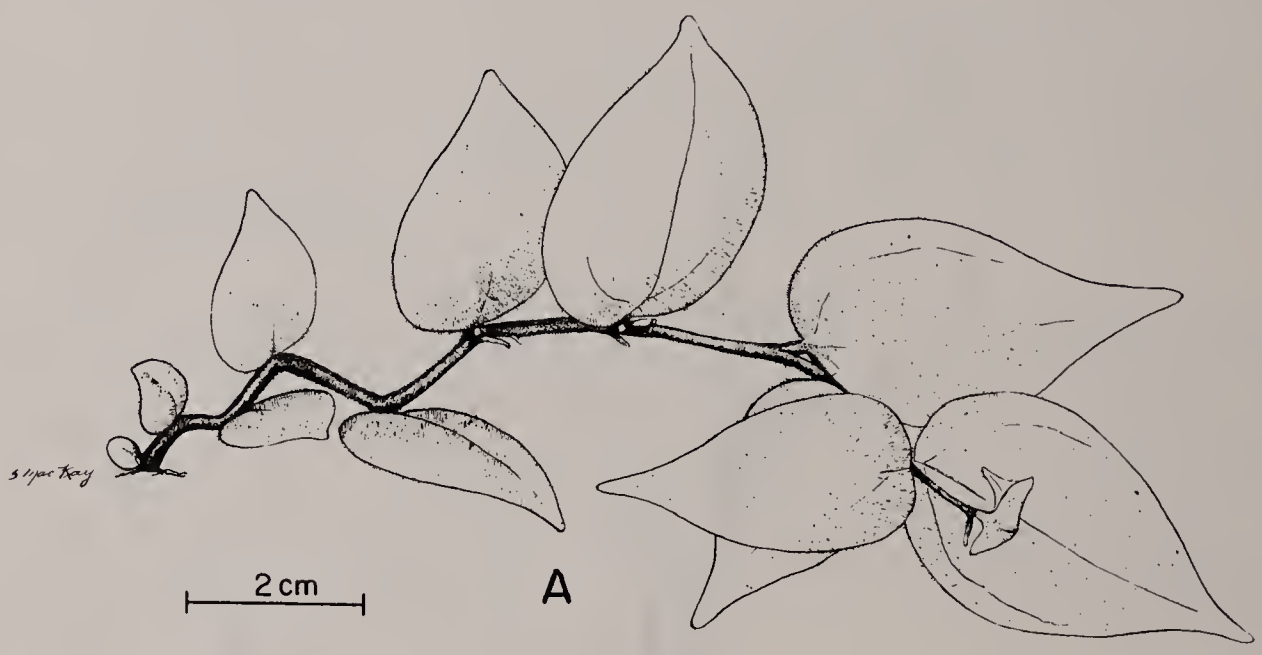
Arching or stiffly erect terrestrial shrub 1.5 to 4 m high, rare at lower elevations, but becoming locally common along the track and in ericaceous shrubberies from 2600 msm to 2850 msm. In full flower during the first week of August. The color of the inflorescence was quite variable: sometimes the axis, calyx, and corolla are brick red; at other times the calyx is white, the corolla red, the style green, and the stamens purple.

14) Dimorphanthera calodon Sleumer.

Erect or straggling terrestrial shrub 2 to 3 m high, occasional along the margin of the track or in dense ericaceous shrubbery above 2500 msm. This species was in full flower during the first 2 wk of August. The local people are said to place snares in front of the tubular corollas in order to trap the birds which pollinate this species.

Fig 3. Seedling of Vaccinium acrobracteatum K. Schumann (ex open pollinated seed; Vander Kloet 86874).

15) Dimorphanthera albida Stevens.
Erect, terrestrial shrub 1 to 3 m high, frequent in the dense ericaceous shrubberies at 2850 msm. This species was in full bloom in the early part of August, which may have resulted in overestimating its relative abundance since its entire inflorescence is white.



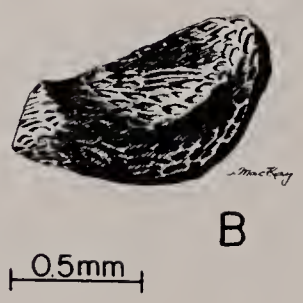


Fig 4. A. seedlings of Dimorphanthera anchorifera J.J.S. (ex open polinated seed (B) Vander Kloet 715874).

16) Dimorphanthera ingens (Sleumer) Stevens.
Erect or scrambling terrestrial shrub 1 to 3 m high, common to frequent above 2500 msm in dense ericaceous shrubberies, on land slips, margin of the moss forest or in open tree fern communities. This species was in full bloom during the early part of August. Major and minor stamens examined were quite similar in size and shape and the major observed difference lies in the arrangement of the tubules: the 5 minor anthers have tubules which clasp together whilst the major anthers have spreading tubules which touch (Fig 5) alternate major stamens.

17) Agapetes brassii Sleumer ssp serratifolia Stevens.
Erect, scrambling, scandent terrestrial or epiphytic shrub 2 to 3 m high, common and locally abundant above 2700 msm. At 2850 msm in the moss forests almost every large tree had a few scrambling vines of this taxon growing along the trunk or in crotches of these trees. It also sometimes grows massed in ericaceous shrubbery. This species was in full flower during August and was the most common vaccinoid epiphyte in the moss forests at 2850 msm. These specimens agree with ssp serratifolia except in flower color which was yellow-red (ssp serratifolia was described as having pale purplish-dirty white corollas).

18) Agapetes vitis-idaea Sleumer.
Stiffly erect, colonial, terrestrial shrub 10 to 30(90) cm high, locally common above 2700 msm associated with Vaccinium amblyandrum. In full flower during August, corolla and calyx reddish-white and pentagonal.

19) Agapetes prostrata Stevens.
Creeping terrestrial shrub, rhizomes superficial, twigs 2 to 5 cm high, seen once in a thick moss carpet on a steep clay bank just off the track at 2700 msm. Beginning to flower in mid-August. This represents a second locality for this species which previously was known only from two collections (one sterile) from Mt. Amungwiwa (Stevens 1972).

20) Diplycosia morobeënsis Sleumer.
Epiphytic, rarely terrestrial, weakly erect colonial shrub 40 to 60 cm high, in crotches of trees from 2250 to 2850 msm; the 10 fallen trunks I examined had at least one or two colonies growing on them and one Nothofagus tree recently fallen had the shrub already reorienting itself with several shoots becoming erect. This species was fruiting and flowering sparsely during August but the few terrestrial shrubs at the margin of the forests were sterile.

21) Gaultheria pullei J.J. Smith
Slender, sometimes arching, usually erect terrestrial shrub 10 cm to 2 m high, strongly aromatic. Most plants were in flower and a few were flowering and fruiting simultaneously. Common above 2600 msm on mass wastage slopes, in fern communities and along the margin of the track in ericaceous shrubberies. Pseudoberries black, each locule contained large quantities of small seeds (6 mg/100 seeds) which germinated readily after storage of one year at 1°C but not when fresh.

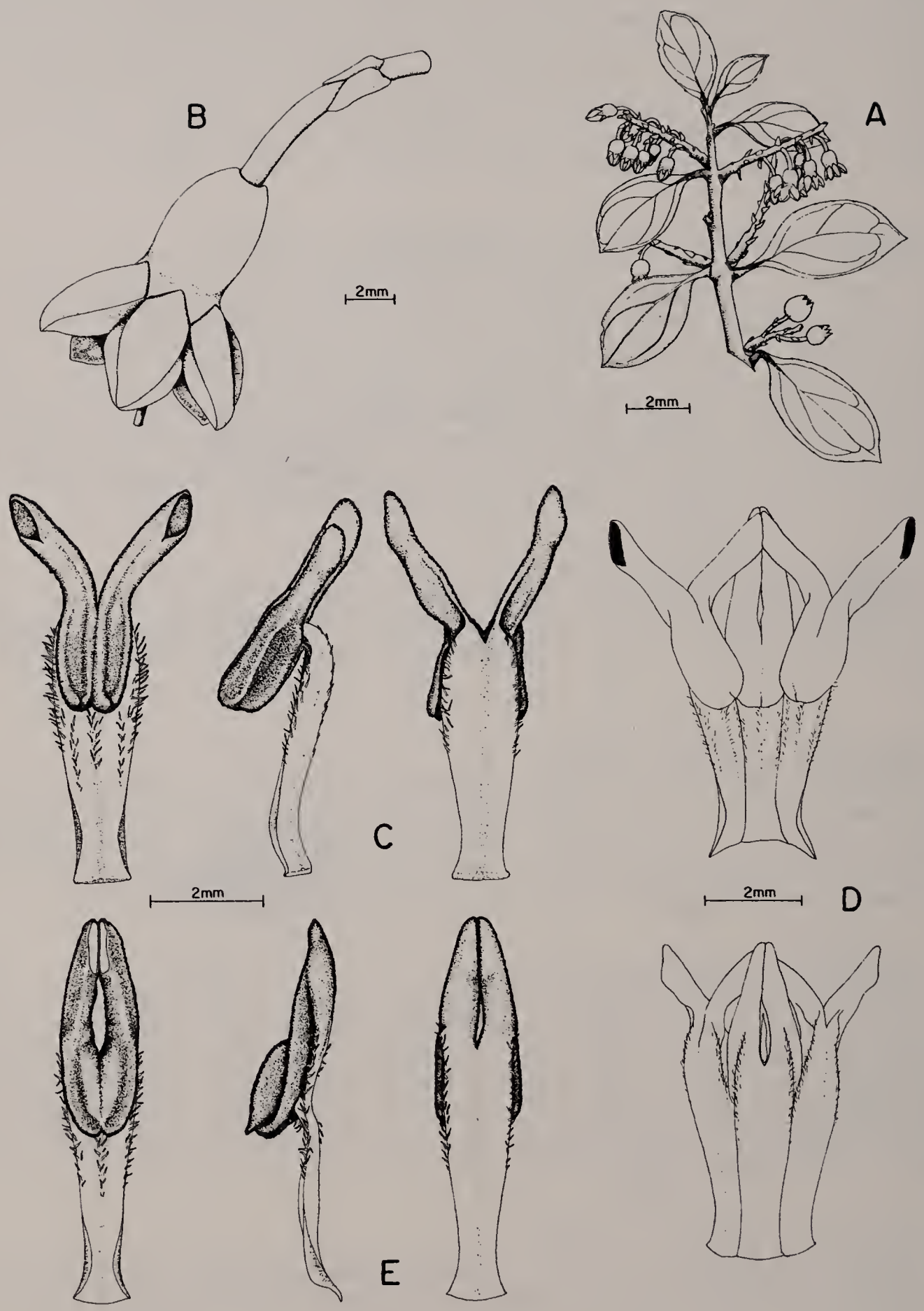


Fig 5. Dimorphanthera ingens (Sleumer) Stevens. (A) habit; (B) flower; (C) major stamens; (D) configuration of stamens; (E) minor stamens.

ACKNOWLEDGEMENTS

I thank Paul Hebert for inviting me to join the expedition and supplying the necessary logistics; I am indebted to Peter Stevens for correcting or verifying my identifications, emending the manuscript, and finally for the type description of Vaccinium morobense. The figures were executed by Suzanne MacKay and Pauline Crouch.

REFERENCES

BRASS, L.J. 1941. The 1938-39 expedition to the Snow Mountains, Netherlands New Guinea. J. Arnold Arbor. 22:271-342.

CAMP, W.H. 1942. On the structure of populations in the genus Vaccinium. Brittonia, 4:189-204.

CAMP, W.H. 1945. The North American blueberries with notes on other groups of Vacciniaceae. Brittonia, 5:203-75.

HALL, I.V. 1959. Plant populations in blueberry stands developed from abandoned hayfields and woodlots. Ecology, 40:742-43.

KEVAN, P.G. 1972. Insect pollination of high Arctic flowers. J. Ecol. 60:831-47.

SLEUMER, H. 1965. The role of Ericaceae in the tropical montane and subalpine forest vegetation of Malaysia. In: Symposium on Ecological Research in Humid Tropics Vegetation, Kuching, Sarawak, 1963. Sponsored by Govt. of Sarawak and UNESCO Science Cooperation Office for Southeast Asia. 376 pp.

SLEUMER, H. 1967. The Ericaceae. In: Flora Malesiana, Vol. 6, (ed C.G.G.J. van Steenis), pp. 469-914. Wolters- Noordhoff Pub., Groningen, Netherlands.

STEENIS, C.G.G.J. van. 1958. Rejuvenation as a factor judging the status of vegetation types: the biological nomad theory. In: Symposium on Tropical Vegetation, Kandy, Ceylon, 1956, pp. 212-18. Study of Tropical Vegetation; Proceedings. UNESCO, Paris.

STEVENS, P.F. 1972. Notes on the infrageneric classification of Agapetes. Notes R. Bot. Gard. Edinburgh, 32:13-28.

STEVENS, P.F. 1976. The altitudinal and geographical distribution of flower types in Rhododendron section Vireya, especially in the Papuasian species, and their significance. Bot. J. Linn. Soc. 72:1-33.

STEVENS, P.F. 1977. Additional notes on Dimorphanthera (Ericaceae). J. Arnold Arbor. 58:437-44.

PROCEEDINGS OF MEETINGS

1976 - 1977

Extraordinary Meeting, 12th August 1976
"Marine Algae of Australia", H.B.S. Womersley, Department of Botany University of Adelaide, South Australia.

1st Ordinary Meeting, 18th October 1976
"The Nova Scotia Research Foundation Corporation and Technology Transfer", J.E. Blanchard, Nova Scotia Research Foundation Corporation, Dartmouth.

2nd Ordinary Meeting, 8th November 1976
"Environmental Aspects of Fundy Tidal Power", G.R. Daborn, Department of Biology, Acadia University, Wolfville, and H.A. Hall, Environmental Protection Service, Department of the Environment, Halifax.

3rd Ordinary Meeting, 6th December 1976
"Our Ocean Giants and Fatty Acids, or What do the Leatherback Turtle and Ocean Sunfish Eat?", R.G. Ackman, Halifax Laboratory, Fisheries and Marine Service, Halifax.

4th Ordinary Meeting, 10 January 1977
"Spruce Budworm Control by Sex Attractants", B.M. Lynch, Department of Chemistry, St. Francis Xavier University, Antigonish.

5th Ordinary Meeting, 14 February 1977
"Ecology of Sable Island: Past, Present, and Future", I.A. McLaren, Department of Biology, Dalhousie University, Halifax.

6th Ordinary Meeting, 14th March 1977
"Canadian Oceanography and Fisheries in the New Economic Zone", L.M. Dickie, Department of Oceanography, Dalhousie University, Halifax.

7th Ordinary Meeting, 4th April 1977 (jointly with the Valley Chapter, Acadia University)
"The role of Saltmarshes in Coastal Processes - A Current Assessment", K.H. Mann, Department of Biology, Dalhousie University, Halifax.

116th Annual Meeting, 16 May 1977
The President, W.D. Jamieson, was in the chair

The Treasurer, H. A. Ellenberger, reported

Receipts	$3,248.56
Expenditures	2,432.10
Permanent Fund	536.89
Total Cash assets as of May 6,1977:	$2,718.49*

* - ($2,510.65 Publication Account, $207.74 Chequing Account)

The Editor, J. McLachlan, reported that Part 3/4 of Volume 27 of the PROCEEDINGS is in the hands of the printer. He said that a NRC publication grant will be requested in the autumn.

The Librarian, Miss Evelyn M. Campbell, reported that the Library of the Institute is in good condition at the Science Library of Dalhousie University. All material of the Library is available to everybody on loan. There has been an increase in the inter-library loan requests from Libraries both in Canada and the United States.

Officers and others elected for the session 1977-1978 were:

President	F.J. Simpson
First Vice-President	P.H. Odense
Second Vice-President	A. Taylor
Secretary	K. Hellenbrand
Treasurer	H.A. Ellenberger
Editor	J. McLachlan
Librarian	E.M. Campbell
Council	H.B.S. Cooke, R.H. Conover, D.S. Davis, I.A. McLaren, T.C. Haliburton (Valley)
Auditors	J.R. Dingle and W.J. Dyer

VALLEY CHAPTER

1st Ordinary Meeting, 6th September 1976
"The Use of Simulation Models as Aids in the Management of Pests Infesting Stored Grain", M. Hardman, Entomology Section, CSIRO, Canberra, Australia.

2nd Ordinary Meeting, 13th December 1976
"The American Dog Tick in Nova Scotia". A. Campbell, Department of Biology, Acadia University, Wolfville.

3rd Ordinary Meeting, 31st January 1977
"Apodan Adventures in Amazonia", T. Toews, Department of Biology, Acadia University, Wolfville.

4th Ordinary Meeting, 21st February 1977
Visit to the Meteorological Station, Canadian Forces Base, Greenwood.

5th Ordinary Meeting, 14th March 1977
"Animals that cause Diseases in Man", I. Ross, Blanchard Fraser Memorial Hospital, Kentville.

6th Ordinary Meeting, 4th April 1977 (jointly with the Halifax Chapter, Acadia University)
"The Role of Saltmarshes in Coastal Processes - A Current Assessment", K.H. Mann, Department of Biology, Dalhousie University, Halifax.

Officers elected for the session 1977-1978 were:

President	T.C. Haliburton
Secretary	F.C. Bent
Treasurer	R. Olsen

TIKVAH EDELSTEIN

1926 - 1977

A Tribute

The many friends of Tikvah Edelstein were very saddened by her death, from cancer, on October 7, 1977, just a few months after her fifty-first birthday. Apart from the loss to her personal friends, her death marked the passing of a skilled and distinguished phycologist.

Our friendship stemmed from our first meeting at the Atlantic Regional Laboratory. Tikvah was a woman with a sincere and sensitive personality. We remember her most of all for her enthusiastic appreciation of the beauties of marine algae, and for her excited calls to all around to share her discoveries in the field or the laboratory. An ardent botanist, Tikvah loved plants, not only the marine plants related to her work, but also garden plants, which were very much in evidence in her home, office, and laboratory and remained one of her chief interests even during her last months.

Tikvah Edelstein was born on June 24, 1926 in Safed, Palestine (now part of Israel). She received her Master's degree in science from the Hebrew University in Jerusalem, and obtained her PhD degree in 1961 at the same university under Professor T. Rayss. Her doctoral dissertation was on the benthic marine algae of Haifa Bay. During the course of her post-graduate studies, she lectured in the biology department at the Technion--Israel Institute of Technology--in Haifa.

With her husband, Dr Michael Edelstein, a mathematician, she came to the United States in the early sixties. She spent her first year in North America at Cornell University with Professor J. M. Kingsbury and the following year at Michigan State University with Professor G. W. Prescott, working on fresh-water algae.

Tikvah emigrated to Canada in 1964, on her thirty-eighth birthday. In December of that year, she was appointed to the staff of the Atlantic Regional Laboratory of the National Research Council of Canada as an algal taxonomist, when the late director, Dr A.C. Neish, decided to expand regional algal exploration.

During her stay at ARL, she worked closely with Dr. J. McLachlan, studying marine algae of the Maritime Provinces and particularly in Nova Scotia. As a result of her efforts, knowledge of the algal flora of this region was greatly expanded, and enriched by her contribution of over fifty publications on local species. To deal with the lack of taxonomic information on some algae, she undertook culture studies, and thus contributed significantly to our understanding of several algal life histories. She is well-known for her discovery of the tetrasporophyte of Gloiosiphonia and completion of the life history of G. capillaris. She also initiated studies on some epiphytic and endophytic algae. At the same time, she established and maintained the marine algal herbarium at ARL, which has become one of the major algal herbaria in eastern North America. She also built up a large collection of references and card files on the regional flora, which are convenient not only for her colleagues at ARL, but also for phycologists in the vicinity.

On a year's staff posting in 1971-72, Tikvah divided her time between the University of California at Berkeley with Professor G.F. Papenfuss, and the University of Adelaide, South Australia, with Professor H.B.S. Womersley. After her return to ARL, she became deeply involved with the morphology and systematics of agarophytic algae, with recent emphasis on Gracilaria. She also belonged to a number of phycological societies, and had been an associate editor of the Canadian Journal of Botany since 1970.

Tikvah Edelstein is survived by her husband; a daughter, Leah; one sister, Mrs. Chava Sdehor; and her parents, Mr. and Mrs. Itzchak Segal. As living memorials to her, Tikvah's friends have had trees planted in Israel and at ARL, in Halifax.

L.C-M. Chen
C.J. Bird

JOHN RUPERT LONGARD

1910 - 1977

John Rupert Longard, one of this country's original group of Defence Research Scientists and member of the Institute, died on New Year's Eve. He had been ill for much of the time since his retirement from the Defence Research Establishment (Atlantic) in the fall of 1975.

Mr. Longard was born, educated, and spent most of his working life in Halifax. At Dalhousie University he majored in Physics and Mathematics, completing his MSc in Physics in 1934. Drs H.L. Bronson, G.H. Henderson, and J.H.L. Johnstone were then the Physics Department and it was the last two who shortly after the outbreak of World War II undertook, at the request of the British Admiralty, organization of the Canadian end of antimagnetic mine warefare.

John Longard had by this time settled down as a successful high school physics teacher, but did not need much urging by Henderson and Johnstone to get into the war effort as an R.C.N.V.R. Lieutenant (Special Branch) designing and testing degaussing coils fitted in Naval and merchant ships in Halifax.

With the countering of the magnetic mine by degaussing, deperming, and electromagnetic mine-sweeping the enemy turned to even more deadly underwater weapons. John soon joined with other degaussing officers and scientists in working on noise devices to sweep the ocean for acoustic mines. The acoustic torpedo followed.

By the end of the War Lieutenant Commander Longard had become involved in the whole field of underwater sound, including sonar, the tracking of submarines by sound echoes. In 1947 he changed over from naval officer to Naval Research Establishment scientist without really changing jobs.

During the following years Mr Longard was able to contribute to the effective use of the bathythermograph in predicting sound propogation in the sea and in the development of variable depth sonar sonobuoys. He was the first Canadian member of the Tripartite Sonobuoy Working Party.

John's wealth of experience was utilized during six years (1954-60) as Scientific Adviser to the Commander, Maritime Command, followed by three years as Scientific Liaison Officer with the Canadian Joint Staff in Washington, D.C.

It was fitting that as a last project before retirement John Longard was asked to write a record of the first years of Canadian Naval Research. His Naval Research Establishment, 1940-67 which he was still tidying up when he became seriously ill last year will be published within the next twelve months.

John is survived by his wife, Evelyn. Associates and other friends will miss their year end "At Homes". The Longard skill and ingenuity even showed itself in original Christmas decorations! Daughter Nancy is married to a Yarmouth High School Science teacher and son, Arthur, is with the Department of Fisheries. There are three grandchildren.

A fitting close to this brief sketch of the life of a quiet, unassuming, gentle and gifted man might be a sentence written inside the cover

of a recently published US Navy volume on operational research by the American friend and collaborator who sent it to John as a gift when he was in hospital:

"To John Longard whose dedication to science and unfailing co-operation assisted ONR, BU Ships and the U.S. Navy laboratories in making great progress in oceanographic research."

E.B Mercer

D. K. R. STEWART

1927 - 1977

Donald Keith Robert Stewart, a research scientist in pesticide residue chemistry at the Agriculture Canada Research Station in Kentville, died on July 6, 1977 of cancer following a lengthy illness. Keith was born on September 22, 1927 in St. John, New Brunswick, and grew up in Halifax. He obtained his BSc and MSc degrees in chemistry and B.A. in history from Dalhousie University. The University of New Brunswick awarded him a PhD in organic chemistry in 1955. Following post-doctoral work with the National Research Council, Keith joined the Kentville Research Station as a pesticide residue chemist in 1957.

Keith was an excellent scientist and early in his career became noted for his work on the fate and translocation of organo-mercury fungicides in plants. He later worked on a wide range of pesticides but specialized on the organochlorine insecticides. Keith contributed much to science and was the author of over 34 scientific publications. He took a great interest in the Nova Scotian Institute of Science. He was secretary of the Valley Chapter in 1967-68 and president in 1970-71. He seldom missed a meeting during his 20 years at Kentville.

Keith was a very unassuming person and in his own quiet way was most helpful to all associated with him. His advice and guidance on all problems in chemistry were freely given and much appreciated by all his associates. Keith had many interests apart from his research. He was a member of the Ken-Wo Country Club, the Glooscap Curling Club, held his private pilot's license in amateur flying, and was an avid camper.

Keith is survived by his widow, Helen Audrey, and three children.

R. G. Ross

INSTRUCTIONS TO AUTHORS

The Proceedings of the Nova Scotian Institute of Science publishes the proceedings of the Institute and original articles, including notes, pertaining to the natural sciences of the Atlantic Provinces, especially in biology and geology. Manuscripts may be either in English or French, and acceptance for publication is based on recommendations of referees.

Manuscripts should be typewritten, double-spaced on white paper 21.5 by 28 cm (8.5 by 11 in) with margins of 4 cm (1.5 in). Underline only material to be set in italics, and use capital letters only when letter or words should appear in capitals in the printed paper. Layout and style should follow that used in this volume. The original copy and one duplicate are required. Each page of the manuscript should be numbered, the first page carrying only the title, authors' names and affiliations, and any necessary footnotes.

Spelling should follow that of Webster's Third New International Dictionary, and authors are responsible for consistency in spelling.

Abbreviations, nomenclature, and symbols for units of measurements should follow international recommendations. Metric units, SI units and decimals should be used whenever possible. Use day/month/year sequence for dates. Do not use periods after such abbreviations as "mm, kg, DOE, NRC, etc."

Taxonomic keys should be in alined-couplet form in zoology and paleontology, and in multilevel indent form in botany. Synonomy in botany, zoology, and paleontology should be in the short form - taxon, author, year:page - with full citation in the references.

An abstract of not more than 200 words should precede the body of the text. This should be followed by an introduction, methods, results or observations, discussion, and references. In some cases a combination of these sections may be more effective.

References should be checked with the original article and referred to in the text by author and date, in parentheses. References should be listed alphabetically at the end of the manuscript. Reference to papers in periodicals must include author, date, title, journal, volume number, and inclusive pagination. Serials are abbreviated in the form given in Bibliographic Guide for Editors and Authors (the American Chemical Society, 1974). For serials not found therein, the abbreviated name in the World List of Scientific Periodicals (Butterworths, 1963) is used. The following are examples of style for references from journals, books, and symposium volumes:

Author, A. N. and Other, T. H. E. 1978. Title of the article. Name of Journal, [volume] 99: 1-10. [Omit word volume].

Author, A. N. and Coauthor, A. 1978. Full Title of Book. Publisher, City.

Author, A. 1978. Title of Article. In Title of Book or Symposium Volume. (ed. J. Smith and B. Jones). Publisher, City, pp. 256-301.

Tables should be numbered with roman numerals, having a brief title, and referred to in the text. Vertical rules should not be used. Tables must be typed separately from the text on individual pages.

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BIOGEOGRAPHY OF *HIERACIUM PILOSELLA* L. IN NORTH AMERICA WITH SPECIAL REFERENCE TO NOVA SCOTIA

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Hieracium pilosella L., mouse-eared hawkweed, is a common or frequently abundant weed of degraded pastures, lawns, cemeteries, roadsides, dunes, and other ruderal habitats in the Maritime provinces and New England. It was first reported from Michigan, yet it is still quite rare in the central United States, Ontario, and Quebec. Although numerous collections exist, especially for the St. Lawrence Valley, they usually represent the first collections for a particular region or county. *H. pilosella* is absent from rough overgrazed pastures in Leeds County, Ontario even where the soil characteristics, such as texture and pH, closely resemble those of Kings and Pictou Co., Nova Scotia, where the plant is abundant. In these latter counties, vegetative propagation is rapid. Each overwintering rosette, concurrent with flowering, produced (2) 5 ± 2 (9)* stolons which elongated during late June to early August at the rate of 1.1 ± 0.3 cm d^{-1} and each of which terminated in a new rosette which under favorable autumnal conditions produced a new set of stolons and rosettes. Regardless of treatment, less than 50% germination was observed.

Introduction

Hieracium pilosella L. is a weedy, rosette-producing hemicryptophyte (Fig 1) which produces 1, occasionally 2, leafless filiform flowering scapes in early summer. Concurrent with flowering, the Nova Scotian populations initiate (2) 5 ± (9) stolons which elongate from late June to early August at the rate of 1.1 ± 0.3 cm d^{-1}; each of these stolons terminates in a rosette which develops adventitious roots, and which, under favorable autumnal conditions, produces a new set of stolons and rosettes. Therefore, under optimum conditions, each overwintering rosette (genet) may add 20 ± 7 additional ramets to the population annually.

It is this basal rosette with its entire setose leaves, white stellate tomentum on the lower surface, and solitary yellow flowering head which serves to distinguish *H. pilosella* from other hawkweed species.

Chromosome counts on vegetative buds *i.e.* immature stolons collected from material growing along the Dominion Atlantic Railway at Wolfville, gave a value of $2n=36$. Voucher specimens are at ACAD. (Herbarium acronyms follow Holmgren and Keuken (1974)). This count is similar to some European populations examined by Turesson and Turesson (1960); these workers also showed that tetraploid populations ($2n=36$) are strictly apomictic.

To substantiate distributional data found in the North American Floras, herbarium specimens were examined at ACAD, QFA, SFS, MTMG, CAN, DAO, QK, TRT; MICH, NYS, GH, NY, US, NCU, and GA. These records indicate that *H. pilosella* was introduced into North America from Europe during the late 19th century. The earliest known record is from northern Michigan, where it was collected by Clark near Benzonia, in Benzie County in 1861 (MICH) and recollected by Voss in 1975 (MICH). Other early stations are London, Ontario, where it was collected successively in 1878, 1879, and 1882, west central New York State in 1883 and 1888, and Prince

*Brackets indicate range, ± one standard deviation.

Fig. 1 Herbarium specimen of *Hieracium pilosella* (ACAD).

Edward Island, where Macoun (1890) reported it to be "completely naturalized" and "very common along road-sides, covering the backs of dykes and the borders of the fields in many parts of Prince Edward Island". Note, however, its absence from pastures.

The inland locations of these early populations, with the exception of Prince Edward Island, suggest that the mode of entry from Europe was not as seed contaminants but rather as packing material, since the provenance of these early collections were cemeteries, lawns, and ruderal habitats.

By 1900 *H. pilosella* had established itself throughout eastern North America in small isolated populations (Fig 2). From 1900 to 1940 *H. pilosella* continued to extend its range, as well as spreading from these founding populations, resulting in many new populations becoming established to form a continuous distribution pattern. By 1937, botanists were finding it in pastures in Nova Scotia and Prince Edward Island. From 1940 to 1970, no further range expansion was observed but local establishment of populations continued, and is continuing especially along the St. Lawrence River system. Figure 2 also shows present Canadian distribution.

The major distortion (which is inherent in any dot map) of this distributional map is that it gives no indication of commonness or rarity of the species. For example Thomas (1972 and *in litt.*) found only 4 small patches of *H. pilosella* within his study area in Wellington County, Ontario whilst in Nova Scotia the plant has become common throughout rough and degraded pastures since its introduction into the province 60 years ago at Pictou (Roland & Smith 1969).

Materials and Methods

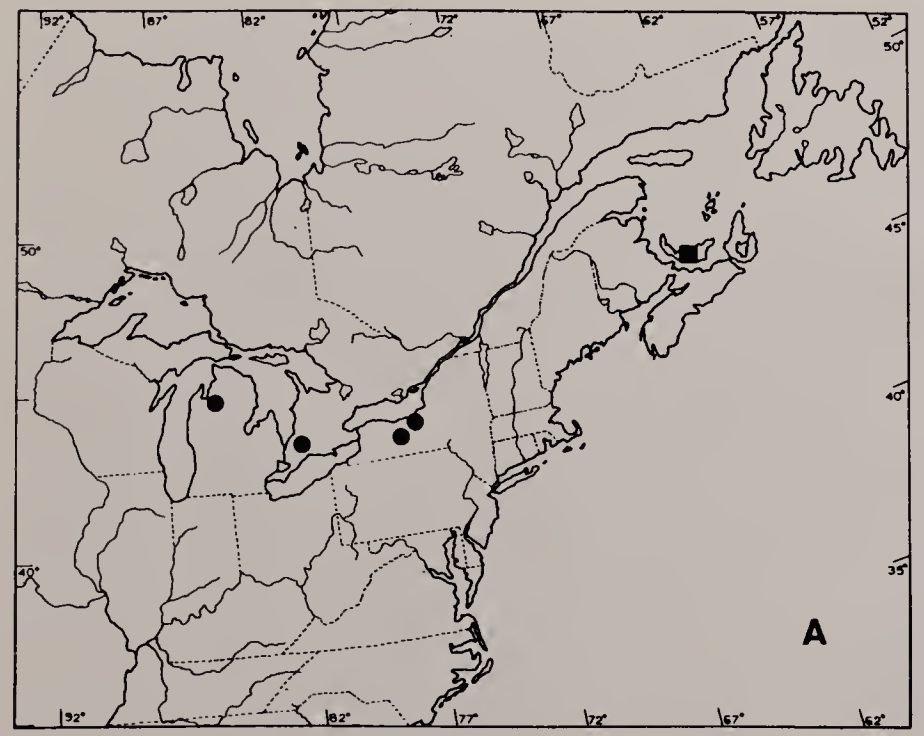
To verify these observations on the commonness and rarity of *H. pilosella* populations, a survey of the vegetation of 4 degraded pastures in Nova Scotia was compared to that of 4 degraded pastures in eastern Ontario.

The Nova Scotia sampling sites were located at West Branch, Pictou County and Gaspereau, Kings Counties; here the soils were gravelly and had a pH of 3.7 to 4.8. The Ontario sampling sites were located near Elgin, Leeds Co. where thin, partially developed soils cover potsdam sandstone pavements; these soils had a pH of 3.7 to 4.8. The other Ontario sampling site was a granite boulder field (soil pH 3.9 - 5.3) between granite outcroppings at Perth Road, Frontenac County.

Frequency of occurrence was assessed by recording plants at dm intervals along 50-m line transects selected at random. Bare ground and litter was recorded as a unit if no species occurred at any given dm-internal point on the transect. Where *H. pilosella* occurred in the pasture, its cover was estimated by throwing 20 quadrats (m^2) at random. The quadrat was gridded at 5 cm intervals (avg of rosette) and the number of rosettes counted from each point intercept. Finally, achenes from 30 to 50 mature capitula were collected for field and *in vitro* germination trials from the following localities: (1) a dune system at West Mabou Harbour, Cape Breton Island; (2) a degraded pasture at West Branch, Pictou Co.; (3) along the dykes at Wolfville, Kings Co.; (4) roadsides of highway 12, south of New Ross, Lunenburg Co.; (5) edge of a poplar regeneration forest, Caledonia, Queens Co.

Achenes were collected from late June through July 1975, 1976 and 1977, stored immediately in envelopes, placed in sealed mason jars, and kept at 1° to 2°C for 1 to 17 mo.

At Wolfville, 3 quadrats of m^2 were cleared along the DAR embarkment adjoining the Canada Vinegar Products Ltd facility; seed beds were prepared, and on the surface of the first quadrat 500 fresh achenes were scattered on 1 July 1975; on the sec-



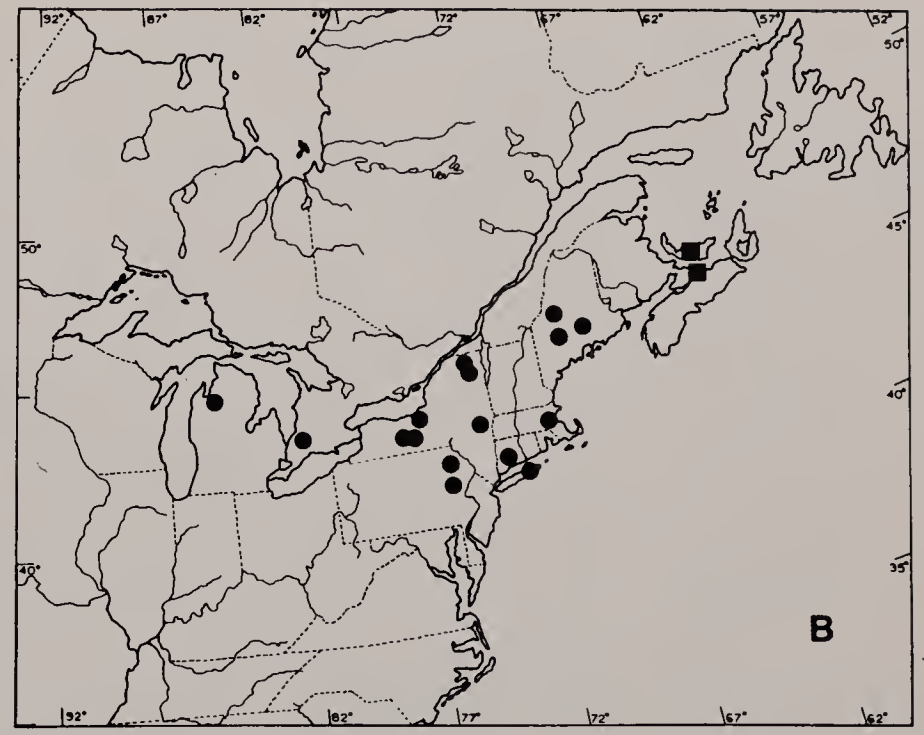


Fig. 2 A-C. Early North American occurrences of *Hieracium pilosella*; (a) 1861-90, (b) 1891-1900, (c) 1901-40; solid dot - herbarium record, solid square - literature record; (d) Canadian distribution of *Hieracium pilosella* based on specimens from DAO, CAN, ACAD, QK, TRT, NYS, NY, GH, MICH, MTMG, and OAC.

ond quadrat, 500 stored achenes were scattered 1 August 1975; and on 1 September, 500 stored achenes were scattered on the third quadrat. No parallel seeding trials were attempted in eastern Ontario, since I did not wish to introduce the Maritime biotype into a region where the species is quite rare and as yet not a pasture weed. Achenes from local populations were too few for any seeding trials.

Seed germination trials were conducted in a growth chamber. Five replicates of 50 seeds representing the five populations were placed on Whatman filter paper in petri dishes, kept moist and subjected to alternating temperatures of 10° and 20°C at a variety of lighting regimes: (1) 8 h light and 16 h dark; (2) 12 h light and 12 h dark; (3) 16 h light and 8 h dark; (4) 24 h light; (5) 24 h darkness. For the second trial, the light conditions were the same as above but, now the temperature alternated between 20° and 30°C.

Results and Discussion

Table I shows that not only is *Hieracium pilosella* absent from the 4 eastern Ontario overgrazed pastures drawn at random but, also that the species composition of the Nova Scotian pastures differs markedly from eastern Ontario. *Echium vulgare, Potentilla recta, P. intermedia, P. argentea, Solidago nemoralis, Poa pratensis, P. compressa,* and *Juniperus virginiana* did not occur in the Nova Scotia pastures sampled whilst *Festuca ovina, Picea glauca, Solidago puberula,* and *Chrysanthemum leucanthemum* did not occur in the Ontario pastures. But as pointed out, the soil texture and soil pH were similar for both regions, and both are in the same plant hardiness zone (Thomas 1953). However, Rowe (1972) has placed these areas into two different forest regions, *viz.*, eastern Ontario, which is part of the Great Lakes Forest Region, and mainland Nova Scotia, which is part of the Acadian Forest Region.

These differences in vegetation may have resulted from small but cumulative climatic differences between the regions such as described by Vander Kloet (1976) and which have given rise to the popular notion of maritime versus continental climates.

Regardless, *H. pilosella* has yet to become established in the rough, rocky, degraded pastures of eastern Ontario. In such a habitat on mainland Nova Scotia, the species is not only frequent but also has high, albeit variable cover values.

Initially, the 1975 field germination trials were not successful, but frequent showers in early September enhanced germination and on 10 September each quadrat, including the one sown on 1 September, had 2, 9, 3 seedlings respectively. Ten days later the seedling density was 37, 23, and 42 for 3 quadrats. By the end of the month, 18 seedlings were well established, the rest were destroyed by drought, high midday temperatures, and browsing.

The *in vitro* germination trials (1975 - 1977) were quite variable (Table II) but successful under all conditions except total darkness. For example, trial 1977, $n=7$, mean germination 19 $\pm$ 12/50 seeds; S.E. 3.3; variance 144. Some anomalies were also observed; achenes collected along the Wolfville dykes consistently had a higher germination rate than those from West Mabou Harbour. The remaining 3 populations gave more inconsistent results; 1976 seed from New Ross germinated quite well but not for the 1977 crop. The same applies *mutatis mutandis* to the Caledonia and West Branch populations.

In conclusion, *H. pilosella* diaspores, when dispersed in a degraded pasture in Nova Scotia, will germinate over at least a 3-mo period. *In vitro* experiments show that the radicle will emerge in 4 d minimum, cotyledons after 6 d, first true leaves after 17 $\pm$ 2 d, second true leaves after 22 $\pm$ 3 d, and an overwintering rosette can be produced in as little as 47 d (58 $\pm$ 13d is the mean). A single overwintering

Table 1. Frequency of occurrence and percentage cover of *Hieracium pilosella* in degraded pastures in eastern Ontario and mainland Nova Scotia.

Species	Nova Scotia		Eastern Ontario	
	Pictou Co.	Kings Co.	Frontenac Co.	Leeds Co.
Hieracium pilosella	438 (63 ± 41%)	351 (26 ± 29%)	-	-
H. aurantiacum	-	1	47	69
H. floribundum	2	136	183	316
Taraxacum officinale	60	1	31	23
Antennaria neglecta	12	131	32	-
Solidaga puberula	13	6	-	-
S. nemoralis	-	-	17	3
Achillea millifolium	106	-	-	-
Chrysanthemum leucanthemum	10	43	-	-
Echium vulgare	-	-	47	31
Potentilla vecta	-	-	3	65
P. intermedia	-	-	42	24
P. argentea	-	-	17	173
Rumex acetosella	16	31	101	35
Vicia cracca	14	-	-	-
Rhinanthus crista-galli	-	12	-	-
Trifolium pratense	-	27	-	-
Festuca ovina	139	368	-	-
Poa pratensis	-	-	122	268
P. compressa	-	-	37	194
Danthonia spicata	145	211	283	122
Agrostis alba	792	153	214	22
Phleum pratense	-	12	7	38
Luzula multiflora	11	12	-	2
Juniperus communis	6	152	125	5
J. virginiana	-	-	38	-
Picea glauca	37	3	-	-
Polytrichum juniperinum	14	39	147	116
P. piliferum	18	23	20	-
Cladonia spp.	25	31	31	33
Byomyces roseus	11	5	-	-
litter, soil, rock	119	183	365	398
others*	12	37	91	63
Total points	2000	2000	2000	2000

*species with less than 5 occurrences each.

Table II. Germination trials of *Hieracium pilosella* from 5 populations in Nova Scotia (1975-1977)

Treatment		Percent germination after 5 d	Percent germination after 10 d
1.1 (250 seeds)	10-20°C; 8 h light	2	19
2.1 (250 seeds)	20-30°C; 8 h light	1.6	43
1.2 (250 seeds)	10-20°C; 12 h light	4	42
2.2 (250 seeds)	20-30°C; 12 h light	9	47
1.3 (250 seeds)	10-20°C; 16 h light	0.3	16
2.3 (250 seeds)	20-30°C; 16 h light	0.9	31
1.4 (250 seeds)	10-20°C; 24 h light	1	8
2.4 (250 seeds)	20-30°C; 24 h light	0.7	13
1.5 (250 seeds)	10-20°C; 24 h dark	0	0
2.5 (250 seeds)	20-30°C; 24 h dark	0	0

rosette, after producing a single capitulum (minimum) which contains 63 ± 24 achenes, will then begin to colonize the adjoining area by sending out 20 to 30 ramets resulting in a mosaic. I have measured patches up to 3 m in diameter. In Nova Scotia the species occurs in a large number of habitats, whilst in Ontario it is scarcely a successful ruderal. Since random sampling could not be used in Ontario, no generalization is attempted, but my suspicion falls on winterkill. The overwintering rosette is quite open and may be destroyed by heavy winter frosts but more experimentation is needed.

References

Holmgren, P.K, and **Keuken, W.** 1974. *Index Herbariorum.* Pt. 1. *The Herbaria of the World.* 6th ed. Oosthoek, Scheltema & Holkema for the International Bureau for Plant Taxonomy and Nomenclature. Utrecht, Netherlands.

Macoun, J. 1890. *Catalogue of Canadian Plants.* Pt. 5. *Acrogens.* Dawson Bros. Montreal, Quebec.

Roland, A.E. & **Smith, E.C.** 1969. *The Flora of Nova Scotia.* Nova Scoita Museum, Halifax, N.S.

Rowe, J.S. 1972. Forest regions of Canada. *Can. Forest Serv. Publ. 1300:1-172.*

Thomas, A.G. 1972. *Autecological Studies of* Hieracium *in Wellington County, Ontario.* Ph.D. Thesis, University of Guelph, Guelph, Ont.

Thomas, M.K. 1953. *Climatological Atlas of Canada. Nat. Res. Coun. Can. Bull.* 3151.

Turesson, G., and **Turesson, B.**, 1960. Experimental studies in *Hieracium pilosella* L. I. Reproduction, chromosome number and distribution. *Hereditas,* 46:717-736.

Vander Kloet, S.P. 1976. A comparison of the dispersal and seedling establishment of *Vaccinium angustifolium* (the lowbush blueberry) in Leeds County, Ontario and Pictou County, Nova Scotia. *Can. Field-Nat.* 90:176-180.

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A STUDY OF A *TSUGA CANADENSIS* STAND IN HEMLOCK RAVINE, HALIFAX CO., NOVA SCOTIA

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Species composition and hemlock (*Tsuga canadensis* (L.) Carr.) age class structure and growth rate were compared for 3 sites (bottom, middle and top) in a hemlock stand on the north-facing side of Hemlock Ravine, located in the City of Halifax, Nova Scotia. This information was used both to assess hemlock habitat quality of each site and as a basis for reconstructing past conditions in the ravine. Overall, the hemlock stand appears healthy with respect to recent reproduction, potential for regeneration, and age class distribution. On the basis of 6 measures drawn from growth rate and age class structure data, there seems to be a gradient of hemlock habitat, from the best and moistest area at the bottom of the ravine slope to the poorest and driest area at the top. The distinct pattern in growth rate observed for all sites over the last century was best correlated with mean March to May temperature. Although it has been emphasized with conifers that water supply is dominant in determining relative annual ring widths, the correlation between precipitation and hemlock growth rate in this study was insignificant. The contribution of canopy opening to the observed peaks in growth rate was also explored. The present healthy existence of this valuable hemlock stand would be adversely affected by increased visitor pressure or a decrease in the flow of the small stream at the bottom of the ravine. Erosion potential would be increased and regeneration decreased (especially on the steep slopes) and the moisture regime would be altered. This study provides baseline data to which future work can be compared and changes detected.

Introduction

Tsuga canadensis (L.) Carr., largely confined to the Hemlock-White Pine-Northern Hardwood Forest delineated by Nichols (1935), reaches its northern limit on Cape Breton Island, N.S. To date, all research on hemlock has been concentrated in the southwestern part of the province (Miles & Smith 1960) where it occurs both in extensive pure stands and with red spruce (*Picea rubens* Sarg.).

This paper reports the study of a hemlock stand (44° 41'N, 63° 39'W) which is isolated on the steep, north-facing slope of a ravine through which a small stream flows. The location of the stand (roughly 0.12 km^2) is shown in Figure 1. The stand is in Hemlock Ravine which was recently (1978) purchased as a Nature Reserve by the City of Halifax in conjunction with the Nature Conservancy of Canada.

Species composition and hemlock age class structure and growth rate are compared for 3 sites (bottom, middle and top) on the ravine-side gradient. This information is used both to assess hemlock habitat quality and as a basis for reconstructing past conditions in the ravine. Field work was done in the autumn of 1976.

Methods

Three plots (10 m by 40 m) were positioned parallel to the top edge of the north-facing slope, one near the bottom, middle, and top. These plots were separated from one another by about 10 m. The lower one was not extended to the stream because of a well-worn foot path adjacent to its edge.

Diameters of all trees with diameter breast height (DBH) $\geq$ 1 cm were measured to

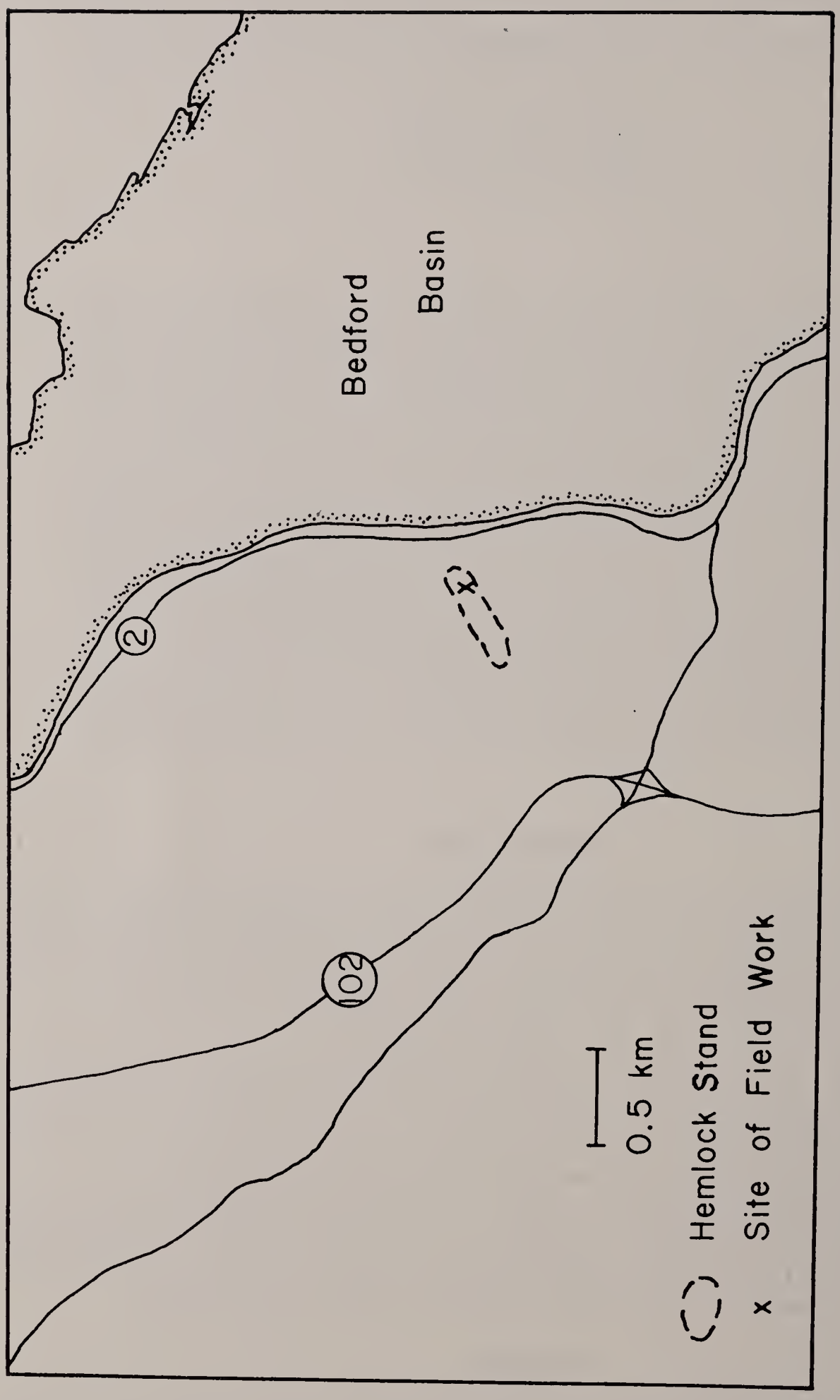

Fig 1. *A portion of topographic map 11D/12 (Halifax, 1: 50,000), (Ed. 4, 1973) showing the location of the hemlock stand studied, between highways 102 and 2.*

the nearest cm and smaller seedlings and saplings were counted in each plot. The ages of a number of randomly chosen hemlocks in each site were determined using an increment borer.

Slope and soil depth were measured to better characterize the three sites. A soil auger was used to measure 20 soil depths over the length of each plot. Slope was measured by a slope meter for 5 locations in each site.

Results and Discussion

Species Composition

Plot compositions are shown in Figure 2 for 3 arboreal species. In the middle and lower sites, hemlock is clearly dominant, followed in abundance by red spruce and balsam fir *(Abies balsamea* (L.) Mill.) However, this is not as obvious in the upper plot. If only large trees (those individuals with DBH $\geq$10 cm = circumference $\geq$ 31 cm) are considered, hemlock is most abundant in the upper plot. The distribution of hemlock will later be examined on the basis of age class structure.

Red spruce appears to be reproducing best near the top of the slope. The ratios of red spruce to hemlock seedlings ($<$ 1 cm DBH) for the 3 sites (bottom, 1:5; middle, 1:1; top, 4:1) increase towards the top. The difference in ratios among sites is significant as a Chi Square Test using seedling numbers from Figure 2 indicates ($X^2 = 99.1$, $p \ll .001$). In the top site, the high potential for red spruce regeneration was clearly shown where a dense cluster of saplings of red spruce and not hemlock had grown up under a hole in the canopy. It is interesting to note that just beyond the top site where the terrain levels off, forest composition changes and red spruce becomes dominant over hemlock.

No balsam fir survived beyond 5 cm DBH. The short life span of balsam fir under hemlock, resulting from intolerance of shading, was noted by Martin (1959) who also found no larger balsam fir.

Betula lutea Michx.f., *Acer rubrum* L., and *A. pensylvanicum* L. are reproducing in the middle plot. In the upper plot, *A. rubrum* seedlings were present, but in the lower plot *A. rubrum* was represented only by a few older trees. Other species present in the plots were: 1) *Fagus grandifolia* Ehrh., *Quercus rubra* L. in the lower plot; 2) *Betula papyrifera* Marsh. in the middle plot; 3) *Betula papyrifera, Fagus grandifolia,* and *Pinus strobus* L. in the upper plot.

Soil depths ranged from 2 to 65 cm and there were no significant differences between depths for any two sites (Mann-Whitney U Test, $= \infty .05$). The slope of the lower plot (9°) was significantly smaller than the slopes of the middle plot (26°) and the upper plot (28°) (Mann-Whitney U Test, $U=0$, $p=.004$). Such steep slopes (stand maximum 36°) have a high potential for erosion which could pose a problem with an increase in visitors to the ravine.

Hemlock Age Class Structure

Age determination A regression line and correlation coefficient for DBH versus age were determined for each plot on the basis of a random sample of trees thick enough (diam. $\geq$ 6 cm) to core. The two largest trees sampled had diameters of 82 cm and 98 cm and were about 286 and 309 years old respectively. These individuals were not used in the regression analyses because they were rotten in the center and their ages could not be determined accurately.

Discs taken from 5 saplings were used to determine DBH and age breast height for a sample of trees too small to core. With data taken from these discs, an age correction factor for the underestimation of age as measured at breast height (1.3 m from ground level) was estimated.

In determining the curve used to obtain age from diameter for trees not cored, a regression line was plotted through the points (age vs diam) for cored trees. The points for the 5 saplings were then added to the graph and a smooth age from

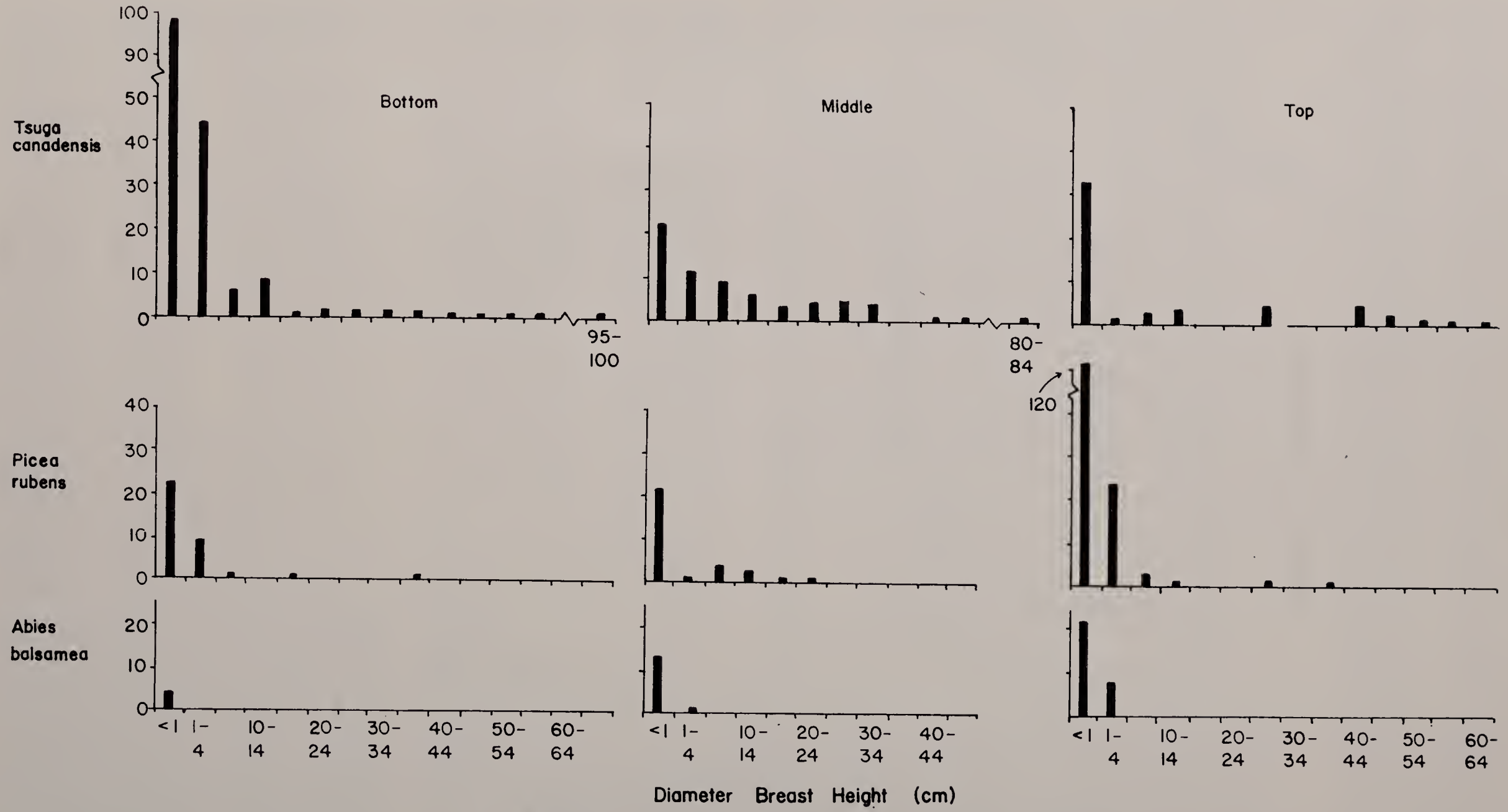

Fig 2. *Diameter class distributions for 3 arboreal species for each of the 3 plots.*

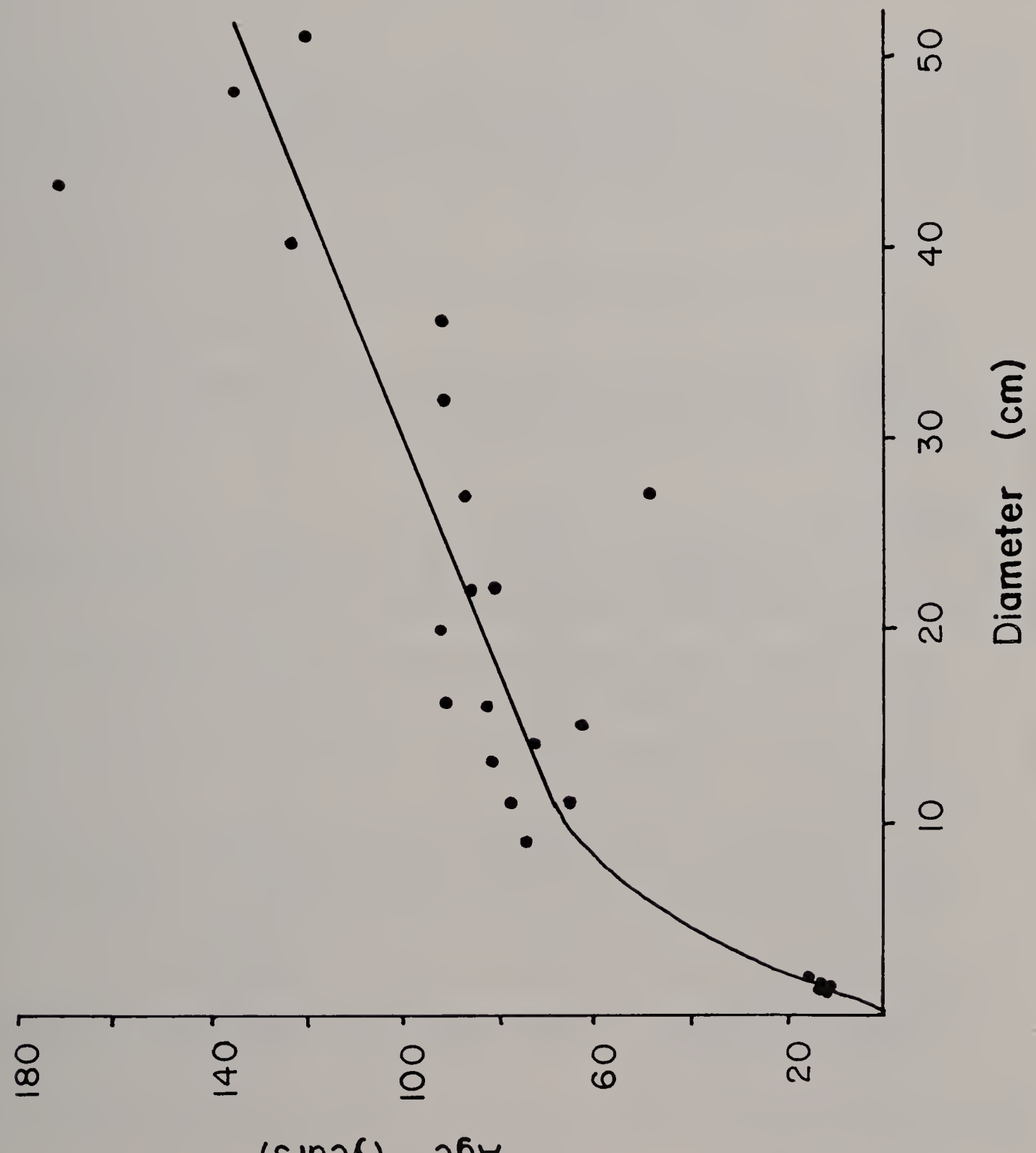

Fig 3. *Age vs diameter curve used to determine age from diameter for trees not cored in the bottom site (regression line: age (yr) = 1.63 (diam. (cm)) + 50.73, correlation coefficient = 0.76).*

diameter for the lower plot is shown in Figure 3. The regression equations and correlation coefficients for the other 2 sites were very similar to those of the bottom site. In each plot less than 5 uncored trees had to be aged using the regression equations.

The 5 saplings varied in age from 17 to 23 years. Errors in age determined at breast height (age at ground level minus age at breast height) for them ranged from 6 to 10 years. Although the age correction factor probably varies with age and possibly site, the mean value of 8 years was added to the ages obtained from cores and to those determined from the age-diameter curves for trees ≥ 1 cm DBH.

Age structure The corrected ages calculated as above were used in the age class distributions shown in Figure 4. The bottom site has the most 'healthy' structure, one where the greatest number of age classes are represented and where frequency gradually decreases with age. Figure 4 indicates that recent reproduction (individuals < 10 years, corresponding to those < 1 cm DBH), presently highest in the bottom site, is relatively good for all sites. Unfortunately regeneration here cannot be compared to stands in southwestern Nova Scotia because there only the percentage of seedlings which was hemlock and not the number of seedlings were recorded (Miles & Smith 1960). This Nova Scotian stand appears comparable to those in New England which also have good natural regeneration (Forbes 1955).

Growth Rate

Comparisons of mean growth rates among sites were made using an analysis of variance (Table I a, b). The trees were not cored parallel to the slope contours, and, because of the steepness of the slope, the annual rings may have grown eccentrically. For these reasons, mean growth rates used in the ANOVA were determined as follows:

$$\text{mean annual radial increment} = \frac{\text{diameter} - (2X \text{ bark thickness})}{2X \text{ breast height}}$$

The complete ANOVA (Table Ib) shows that there is a significant difference in growth rate among age classes and among sites. Significant interaction indicates a difference in age structure among the 3 sites (Fig 4).

Habitat Assessment

Intuitively one might suggest from Figure 4 that there was a gradient in hemlock habitat from good (bottom) to fair (middle) to poor (top). Several quantitative measures can be considered in assessing habitat quality, including:

1) the number of age classes represented (Fig 4); although this is a function of classification interval, all sites were classified the same way.
2) the number of seedlings surviving to establish over the past 10 years (Fig 4)
3) the number of mature individuals (those $\geq$ 10 cm DBH, corresponding to those ≥ 60 years) established in the last 100 years.
4) the number of age classes where mean growth rate is highest (see Table I a).
5) mean maximum radial increment over 1 decade (using trees of similar ages)
6) mean of mean radial increment per decade (using trees of similar ages).

With regard to 5 and 6, the increase in radial increment for each decade, 1967 - 1976, 1957 - 1966 . . . to 1866 was recorded. Trees greater than 90 years old

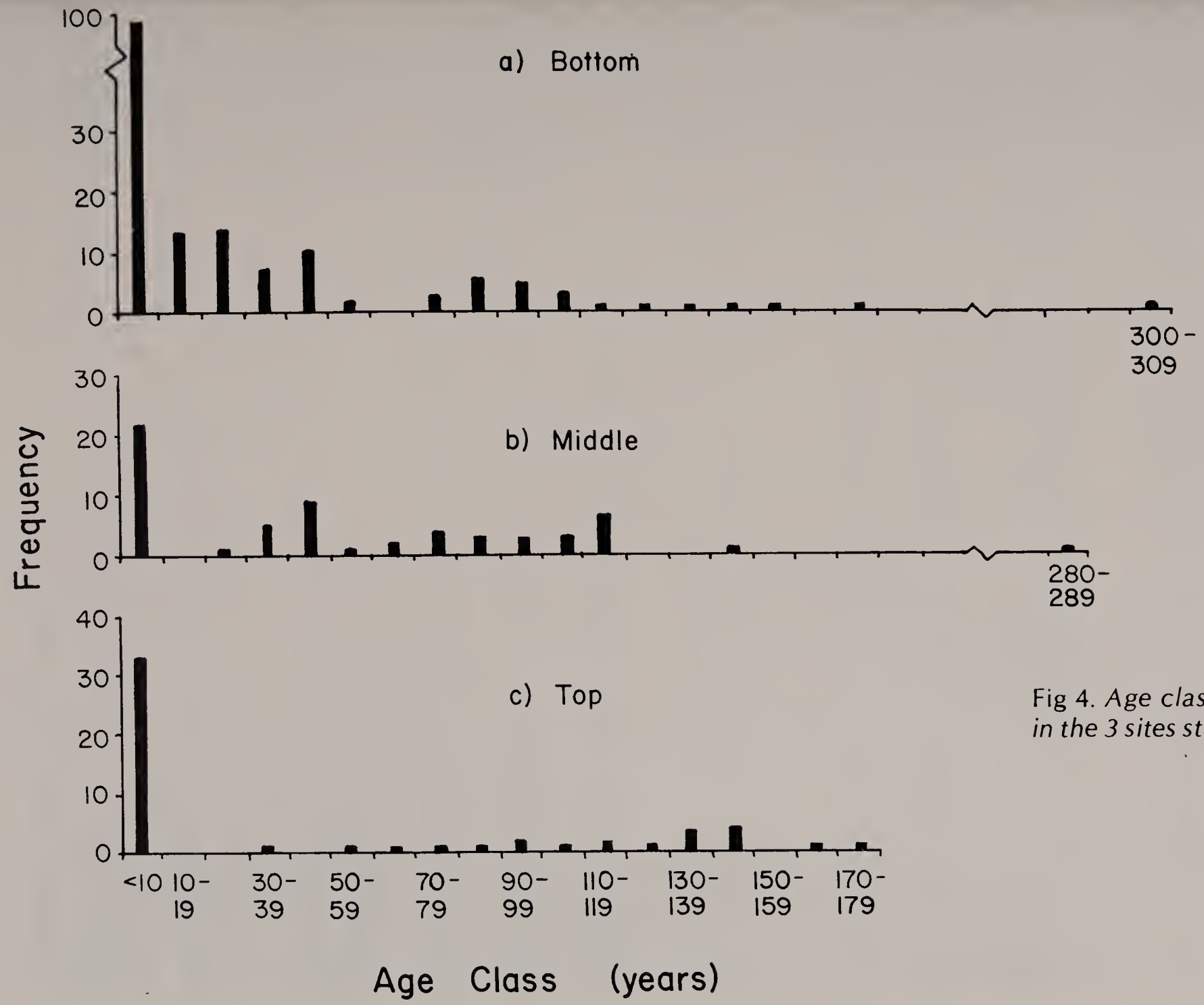

Fig 4. *Age class distribution for hemlock in the 3 sites studied.*

Table I Analysis of variance for growth rate vs site and age.

(a) means of mean annual radial increment in mm.

Site	Age Classes (years)					
	30-49	50-69	70-89	90-109	110-129	130
Bottom	2.67	0.97	0.96	1.34	1.80	1.45
Middle	0.87	0.77	0.86	1.65	0.81	0.87
Top	0.96	0.63	0.85	1.52	1.92	1.42

(b) complete ANOVA

Source	SS	df	MS	F	
Age	3.65044	5	0.73008	4.94	(p .01)
Site	2.13534	2	1.06767	7.22	(p .01)
Interaction	4.96489	10	0.49649	3.36	(p .01)
Error	7.54290	52	0.14790		

Table II Values of hemlock habitat measures for 3 study sites.

Habitat Quality Measure	Site		
	bottom	middle	top
no. age classes represented	17	13	14
No. seedlings established in last 10 years	98	22	33
no. mature trees established in last 100 years	14	12	5
no. age classes having highest mean growth rate	4	1	1
mean maximum radial growth over 1 decade (mm)*	24.2	23.3	23.2
mean of mean radial increment per decade (mm)*	13	14	13

*no. of trees in sample: bottom-12, middle-14, top-13

were used because this gave a number of decades with which to work and this group was probably under the least suppression (because of shading). The values of these measures were determined for the 3 sites and are shown in Table II. The first 3 measures of habitat suitability are related to regularity and abundance on regeneration; they suggest that the best hemlock habitat is at the bottom of the slope, next to the stream. This is also supported by the first measure based on growth rate. However, the last two measures indicate that for trees greater than 90 years old, all sites are equally good habitat.

Based on both measures from age class structure and growth rate, there indeed appears to be a gradient in hemlock habitat, with the best at the bottom. This is supported by Oosting and Hess (1956) who worked with hemlock on a north-facing ravine slope in North Carolina. In their study, hemlock was found near the stream in the bottom of the ravine and it diminished in abundance towards the top of the slope, with oak (*Quercus sp*) eventually replacing it at the top. Several authors have noted that hemlock seedlings tend to do best on the moister areas (Black & Mack 1976; Hough 1939; Stearns 1951). This suggests that the apparent gradient in habitat may result in part from a corresponding moisture gradient.

Tree Ring History

In the 17th century, the annual character of tree rings was fully recognised (Studhalter 1955). Since that time they have been used to date glacier advances and retreats, landslides, erosion cycles and as an index of past climatic conditions (Glock 1955).

When mean radial increment per decade for hemlock was plotted against time, the same pattern was found for all three sites regardless of their differences in age class structure and growth rates (Fig 5). How is this growth ring history to be interpreted? As Schulman (1941) noted, the observed growth rates depend on a variety of factors. Here a few climatic factors and the possible influence of man will be discussed.

One might expect rainfall to be most critical from May to August when the temperature is most suitable for rapid growth, and that ring width would be a good index of precipitation during this period. Comparisons of mean May to August and mean annual precipitation to growth per decade showed that this was not the case. Correlation coefficients were not significant.

There are several possible reasons for this unexpected relationship. The effect of precipitation may be offset by other factors. Secondly, precipitation received may not be a measure of water availability, to which the trees respond. Thirdly, the observed increase in radial increment per decade is to some extent inaccurate because it was determined from only 1 core per tree and eccentric growth is to be expected on such steep slopes. An additional factor which may be obscuring the relationship is the use of means over a decade rather than yearly growth and precipitation. The possibility that there is no relationship also exists.

Temperatures from June to August are generally suitable for growth and those from September to February are cool with growth being minimal. Therefore, temperatures from March to May were selected to be compared to growth because they determine spring water supply (from ice and snow) and the starting date for the season of rapid growth. Both the growth rate curves (Fig 5) and the temperature curve (Fig 6) have corresponding peaks and hollows. The correlation coefficient for these two variables is 0.51. Of the 2 factors, precipitation and temperature, the tree ring widths are better correlated with temperature (when working with decades).

In other work concerning the relationship between tree growth and temperature and precipitation, some authors have obtained good correlations for hemlock (Lyon 1943). Glock (1955) says of Lyon's work with hemlock, " . . . the correlations between relative growth rates and the precipitation records of certain periods of the year

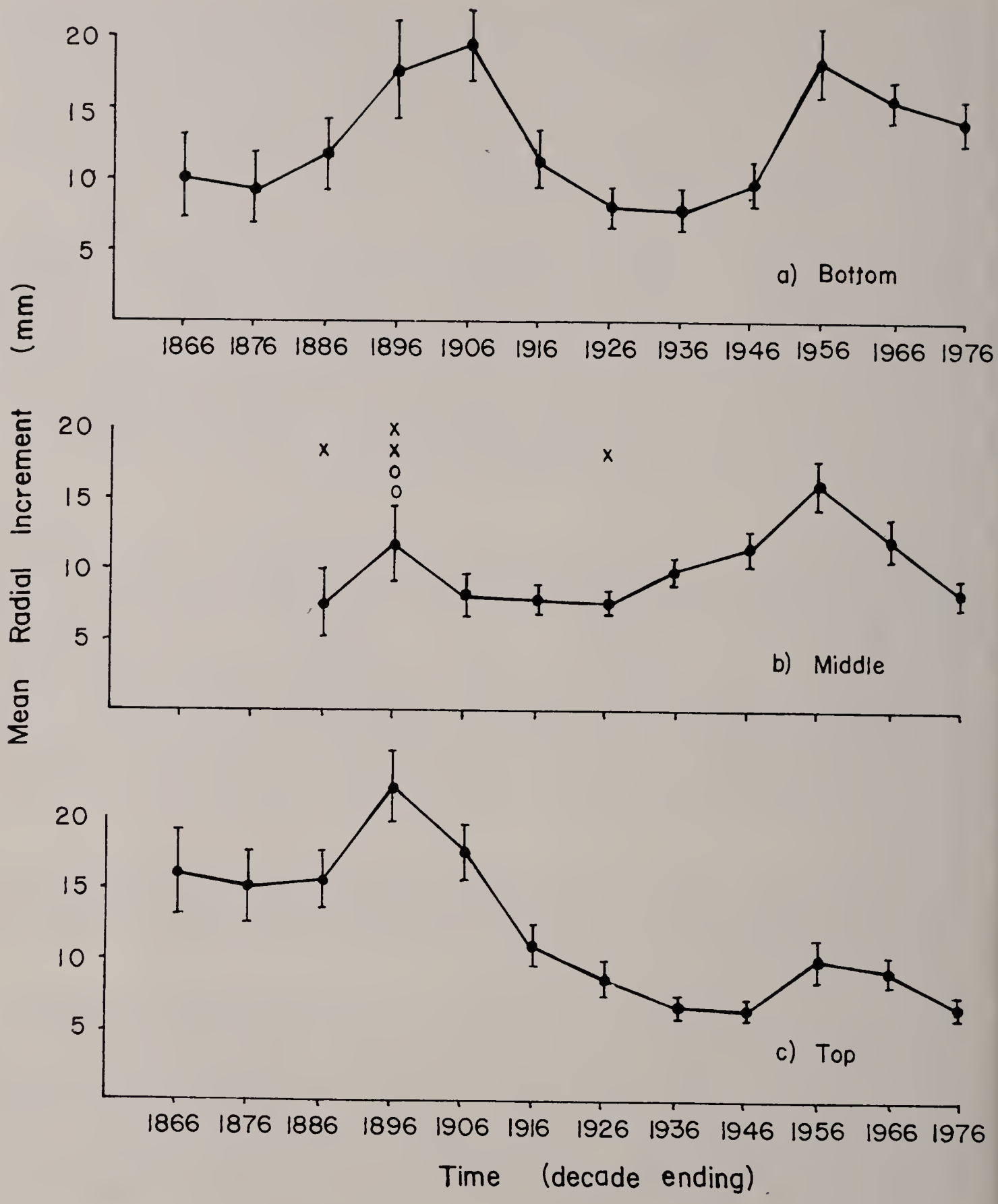

Fig 5. *Mean growth per decade for all trees cored in each plot; bars indicate 95% confidence intervals for means; x = decade of establishment of white birch cored, o = decade of establishment of red maple cored.*

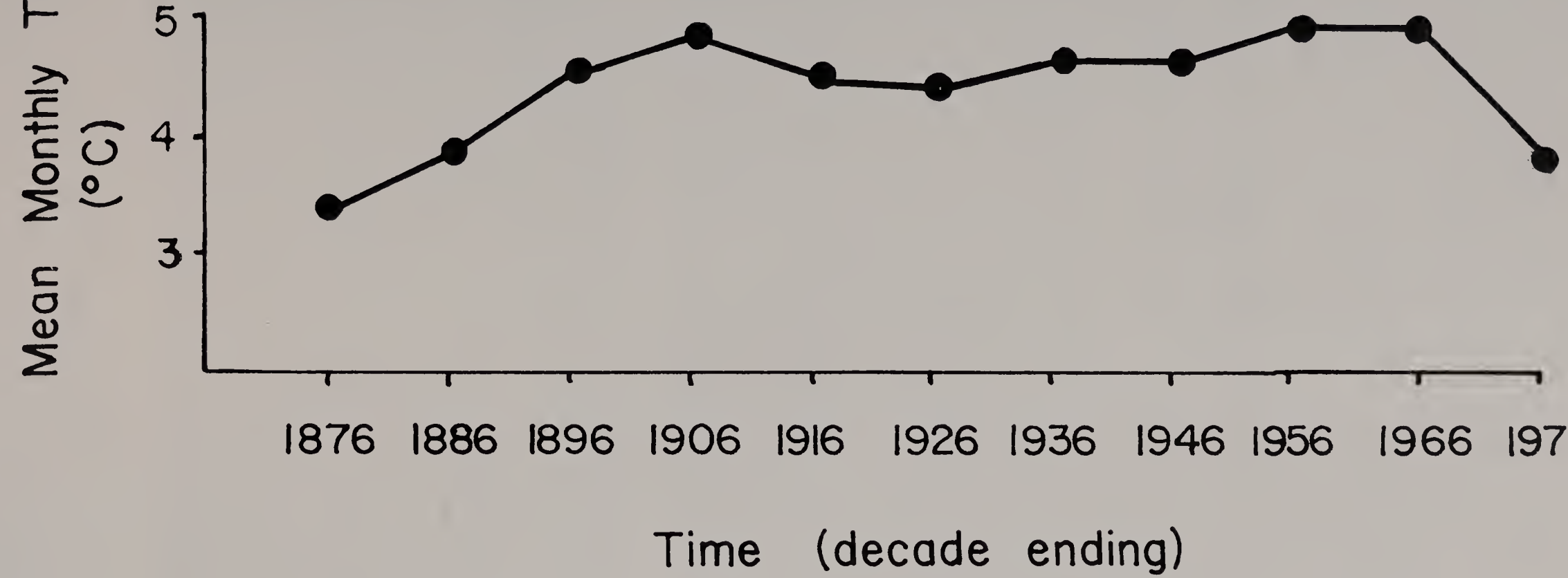

Fig 6. *Temperature data for March to May for decades indicated; data from the Halifax station.*

(May to July, May to August) are so high that the occurrence of a notably narrow or wide ring of wood is presumptive evidence for a drought or generous supply of water". On the other hand, various authors (Avery *et al.* 1940; Meyer 1941) found an insignificant correlation between hemlock ring width and precipitation. Clearly, the use of tree ring records as a reliable measure of climatic factors can be made only when one eliminates variation in ring width resulting from other factors (e.g. trend with age). When this was done for hemlock, Shumacher and Day (1937) found that it was a good indicator of moisture conditions.

Growth rate can also be affected by the degree of canopy opening. This could be brought about naturally by storms and hurricanes or artificially by the selective removal of valuable timber trees. Creating gaps in the canopy would also enhance the establishment of other less shade tolerant species. With this in mind, ages were determined from cores for 4 white birch (*Betula papyrifera*) and 2 of the red maples (*Acer rubrum*) found within the plots. Figure 5b shows that of the 6 trees, 4 probably started to grow during the decade ending in 1896, one of the earliest peaks in growth. None was close to the 1956 peak. These results suggest that canopy opening may have played a part in the early peak.

Over the years there has been a number of intense North Atlantic hurricanes (1935, 1938, 1944, 1966) which affected Nova Scotia. The first 3 may have contributed to the 1956 peak through increasing canopy opening, but this was not reflected by the establishment of shade intolerant species. No major storms were recorded around the time of the early peaks.

Artificial canopy opening through man's activities is the second possiblility. There is no field evidence to support this as a factor contributing to the 1956 peak. With regard to the early peaks and artificial canopy opening, I spoke to a number of people including H. Haverstock, owner of the nearest sawmill (established 1850), the Nova Scotia Museum's authority on ship building in the area, and Lou Collins, an official of Heritage Trust. Documents from the Nova Scotia Public Archives (Harris, Mullane, Smith, Storey) were also consulted. None of these sources indicated that wood had been taken from the ravine for any purpose at the turn of the century or at any other time. Perhaps the relationship between the establishment of the white birch and red maples and the growth peak is not evidence for general canopy as hypothesized earlier, and it is by chance that the two occurred at the same time.

It should be recognised that Hemlock Ravine is of great value to the Halifax-Dartmouth area. The hemlock stand in this ravine is several centuries old and relatively untouched by man. Yet, this unique natural feature is within reach of a large urban population. Here exists ample opportunity for education in natural history and biological processes.

This study has shown that the hemlock stand in Hemlock Ravine is healthy, having good recent reproduction, potential for regeneration, and age class distribution. There are 2 main factors critical to the maintenance of the health of this valuable stand which should be kept in mind with any management consideration and in the development plans for the surrounding area. Increased visitor pressure, especially on the steep slopes, will increase the potential for erosion and decrease hemlock regeneration. Secondly, special attention should be paid to the small stream in the bottom of the ravine. This stream influences the moisture regime which is critical in the establishment of hemlock seedlings. Hopefully this study will serve to provide baseline data to which future work can be compared and changes detected.

Acknowledgements

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References

Avery, G.S., Creighton, H.B., and **Hock, C.W.** 1940. Annual rings in hemlocks and their relation to environmental factors. *Am. J. Bot.* 27: 825-831.

Black, R.A. and **Mack, R.N.** 1976. *Tsuga canadensis* in Ohio: synecological and phytogeographical relationships. *Vegetatio* 32: 11-19.

Forbes, R.D. 1955. *Forestry Handbook.* The Ronald Press Co., N.Y.

Glock, W.S. 1955. Tree growth II: growth rings and climate. *Bot. Rev.* 21: 73-188.

Harris, R.V. 1908. Around the Bedford Basin. *Acadiensis* 8: 12-31. N.S. Public Archives.

Harris, R.V. *A Scrapbook on Bedford Basin.* (No. MG1 vol. 368, no.1) N.S. Public Archives.

Hough, A.F. 1939. A climax forest community in Eastern Tionesta Creek in northwestern Pennsylvania. *Ecology* 17: 9-28.

Lyon, C.J. 1943. Water supply and the growth rates of conifers around Boston. *Ecology* 24: 329-344.

Martin, N.D. 1959. An analysis of forest succession in Algonquin Park, Ontario. *Ecol. Monogr.* 29: 187-218.

Meyer, H. 1941. Growth fluctuations of virgin hemlock from northern Pennsylvania. *Tree-Ring Bull.* 7: 20-23.

Miles, M.L. and **Smith, E.C.** 1960. A study of the origin of hemlock forests in southwestern Nova Scotia. *For. Chron.* 36: 375-390.

Mullane, G. *Footprints Around Bedford Basin.* (No. F107, B39, M91) N.S. Public Archives.

Nichols, G.E. 1935. The hemlock-white pine-northern hardwood region of eastern North America. *Ecology 16: 403-422.*

Oosting, H.J. and **Hess, D.W.** 1956.Microclimate and a relict stand of *Tsuga canadensis* in the lower Piedmont of North Carolina. *Ecology* 37: 28-39.

Shulman, E. 1941. Some propositions in tree-ring analysis. *Ecology 22: 193-195.*

Schumacher, F.X. and **Day, B.B.** 1937. The influence of precipitation upon the width of annual rings of certain timber trees. *Ecol. Monogr.* 9: 387-429.

Smith, T. 1801. *Forest Survey of Nova Scotia.* (No. RG1, 380-380a) N.S. Public Archives.

Stearns, F. 1951. The composition of the sugar maple-hemlock-yellow birch association in northern Wisconsin, *Ecology* 32: 245-265.

Storey, D.A. 1926. *Bedford Basin. In* Papers of the Nova Scotia Historical Society, N.S. Public Archives.

Studhalter, R.A. 1955. Tree growth I: some historical chapters. *Bot. Rev. 21: 1-72.*

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MINUARTIA GROENLANDICA (CARYOPHYLLACEAE) IN NOVA SCOTIA

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The history of the discovery of *Minuartia groenlandica* in Nova Scotia is reviewed and 3 new localities, in Queens, Halifax, and Lunenburg Co., are reported bringing the recorded number of sites to 6. The habitat at the Kidston Lake barren is described and the persistence of the species at the site is ascribed to the presence of a very shallow soil on an impervious rock pavement which prevents the establishment of competing species. Although an arctic–alpine, *M. groenlandica* is not associated in its Nova Scotian habitats with any other arctic-alpine plants and the same applies to its other lowland sites in eastern United States. Its occurrence in these lowland sites is apparently determined by its ability to survive summer drought by means of the seed phase, an ability not commonly found among arctic-alpines. The intermediate nature of the Nova Scotian plants between the southern populations (var. *glabra*) and the arctic-alpine form is explained as a local adaptation to our intermediate and unpredictable summer weather.

Introduction

*Minuartia****groenlandica* (Retz.) Ostenf. the Greenland sandwort, is one of the rarer plants in the Nova Scotian flora. It is a small (2-10 cm high), white-flowered herb belonging to the chickweed family and for 60 years was known in Nova Scotia from only a single collection which could not be confirmed since the locality given on the label proved to be misleading. Recent discoveries and a study of its habitat indicate that it may be much more common than hitherto suspected and the purpose of this paper is to describe its distribution, habitat and life cycle.

History of Discovery in Nova Scotia

John Macoun, the Dominion Geologist, was the first person to report the species in Nova Scotia (Macoun 1886). He distributed specimens to several herbaria and the sheet at BM (herbarium acronyms follow Holmgren and Keuken 1974) has written on the label 'No. 287, *Arenaria Groenlandica,* Spreng. On rocky ground North West Arm, Halifax, N.S. Macoun, 5/19/83'. The 2 specimens on this sheet are quite typical of the Nova Scotian populations and appear to represent plants derived from seeds which had germinated early in the previous autumn.

It was not until 1943, 60 years after Macoun's report, that Eville Gorham found the species on the Kidston Lake barren near Halifax (UTM map reference ME512377) ending speculation that Macoun had not found the plant in Nova Scotia at all but had mixed up his collections with plants from farther north. Then in 1947 R.G.S. Bidwell and S.M. Mason found another colony only 8.5 km NW of Kidston Lake on

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***In North America often put into* Arenaria *sensu lato following Fernald (1919). Modern authors (e.g. Komarov 1934-1964, Tutin et al. 1964-), however, have split* Arenaria *into a number of smaller genera and the species discussed in this paper falls into* Minuartia. *The latter name has now been adopted for Flora North America (Shetler & Skog 1978) and seems likely to be used generally in future.*

'Flagmast Hill, west of Geizer Hill'; this refers to the area of barrens south of Susie Lake and although the name 'Flagmast Hill' does not appear on the National Topographic 1:50,000 series of maps, the reference is to a small hill of about 130 m altitude (ME 458442). Following that, P.A. Bentley in 1956 discovered a more remote population (but still in Halifax Co.) on climbing to the top of Gibraltar Rock in the Musquodoboit Valley some 46 km NE of Kidston Lake (ME 805705). After a lapse of a further 20 years a colony of plants was discovered quite by accident north of Big Tupper Lake in Queens County (LE 393245) by W.A. Silver in October 1975. This is some 110 km west of the two populations near Halifax, but consists of a granite barren with much the same general appearance. This led to the suspicion that there may be patches of the plants on many more of the barrens of Nova Scotia. On being alerted, P.A. and C.J. Keddy found yet another population, this time in Lunenburg Co. near Blue Rocks east of Lunenburg in 1977 on a coastal barren (ME 105126), not many meters above sea level. In spring 1978 M.J. Harvey found several small, scattered populations near Quarry Lake (ME 453462) just 2 km north of the Flagmast Hill site; this is not separated from the latter in Figure 1 which shows the known Nova Scotian sites. It seems obvious that more populations remain to be discovered.

Except for the Macoun record where material was examined at BM, the above information is taken from herbarium specimens deposited in DAL. The records up to 1956 have been reported in Roland and Smith (1969), and all known localities are shown in Figure 1.

Distribution Outside Nova Scotia

The distribution and habitats of *M. groenlandica* outside Nova Scotia should be mentioned since they have ecological and taxonomic implications which have to be taken into account when making decisions about the status of the Nova Scotian material. However, it is not the intention to discuss anomalies of distribution or the taxonomic situation in this paper; suffice it to say for the taxonomy that two varieties, var. *groenlandica* and var. *glabra*, often regarded as species (e.g. Weaver 1970), have traditionally been distinguished. For the purpose of this paper, we regard both forms as belonging to one species—*M. groenlandica* sensu lato.

In North America the distribution may be regarded as having two components: first, eastern arctic-alpine distribution from Greenland, Newfoundland, and Quebec down the Appalchian peaks as far as North Carolina and Tennessee; second, a coastal plain-piedmont distribution from Nova Scotia to Tennessee, Georgia, and Alabama (Seymour 1969; Radford et al. 1968; Weaver 1970). Hulten (1964) presents a world map and draws attention to the curious occurrence of the species in southern Brazil.

Materials and Methods

Vegetation analysis was carried out using a series of permanent strip transects 10 cm wide and of varying lengths laid out across the lichen and shrub zones in 4 separate areas. Plant species and soil depth were recorded in each 10 cm section of the transect. Lines painted on the adjacent rock surface enabled the transects to be relocated, thus enabling the appearance and disappearance of *Minuartia* seedlings in the various zones to be recorded; although the detailed results of this are not presented, they are referred to briefly in the discussion.

Soil samples were collected from a series of 4 standard stations at intervals throughout the summer of 1975, sealing each immediately in a 'Whirl-Pak' polyethylene bag to prevent loss of moisture. Moisture content was determined by drying weighed samples in an oven at 70°C and organic matter by burning samples of the dried soil in a muffle furnace. In turn the ash and a sample of ash from similarly burnt *Minuartia* plants was subjected to qualitative spectrographic

Fig 1. Map of Nova Scotia showing a) sites from which *Minuartia groenlandica* has been collected to 1977. b) distribution of granite (from the Geological Map of Nova Scotia, N.S. Department of Mines).

analysis in a Baird Atomic RDRS Spectrometer Model GX-3, as was a soil sample from the Tupper Lake site.

In addition to the above analyses, a number of samples of soil and various species of lichen in a fresh, apparently active, moist state as tested for the presence of nitrogen-fixing ability using the acetylene-reduction technique. No activity was detected and the subject was not followed further.

Results

Figure 2 shows in diagrammatic form the general results obtained from the vegetation transects. The vegetation has been divided into a series of 6 zones according to soil depth, and we have adopted the numbering system used in a similar survey by Oostings and Anderson (1939).

Zone 0 lacks any soil or vascular plants and consists of the exposed rock surface with a variety of crustose and thallose lichens and mosses, the lichens include *Parmelia centrifuga* and *Stereocaulon* spp among the more conspicuous.

Zone 1 has soil up to about 2 cm deep, averaging 1 cm, with often a conspicuous growth of the lichen *Cladonia papillaria* where Zones 0 and 1 meet. *Cladonia boryi* is the dominant lichen and probably contributes the majority of the about 8% black, fiberless humus in the soil. *M. groenlandica* is the only vascular plant to occur in this zone.

Zone 2 has soils 2 to 4 cm deep with about 12% organic matter, is dominated by the same lichens as Zone 1, but supports a sparse vascular flora of *Danthonia spicata, Carex umbellata* (*C. tonsa*), *Panicum subvillosum*, and *Potentilla tridentata* — the latter being the more abundant. No mature *Minuartia* plants are found in this zone.

Zone 3 has soils from about 4 cm to as much as 20 or 30 cm but averages 10 cm. Lichens again dominate with abundant growth of the sub-shrub *Corema conradii*, lesser amounts of *Vaccinium angustifolium*, and occasional small plants of other shrublets such as *Epigaea repens* and *Gaultheria procumbens*. These soils contain about 15% organic matter.

Zone 4 has soils of 20 cm or more deep, with a humus composed of a greater proportion of fibrous material derived from the dense shrub growth. A few tree seedlings of *Picea mariana* are found, but grow in a very stunted manner probably because the soil is underlain by impervious granite and becomes dried out in occasional droughts thus sapping the growth of trees. Shrubs dominate with *Kalmia angustifolia* and *Gaylussacia baccata* abundant and lesser amounts of *Nemopanthus mucronata, Vaccinium angustifolium, Ilex glabra, Amerlanchier* spp, *Aronia prunifolia* and *Rhododendron canadense* occurring throughout the region.

Zone 5 is the scrub forest and is developed on the more broken areas of granite where the depth of humus is sufficiently deep or the rock is sufficiently cracked to allow for an adequate supply of moisture to support tree growth. The soil has nearly 90% organic matter. *Picea mariana, Acer rubrum* and *Betula papyrifera* are abundant but several other trees such as *Pinus strobus, P. banksiana*, and *Populus grandidentata* are present as is a rich shrub and herb layer. The microclimate of Zone 1 was obviously different from the adjacent shrub and woodland habitats. Lacking instruments to measure factors such as surface wind velocity, surface temperature, insolation, humidity, dew, and mist collection, we decided to follow soil moisture content over the 1975 growing season since it seemed that this would act as an integrator for the microclimatic regime in the different zones.

The first soil samples were taken in May after the beginning of the growing season for *Minuartia* when the soils had a high water content and at intervals until the onset of cool, wet weather in September. From October to April there is unlikely to be any drought. The results are presented in Figure 3.

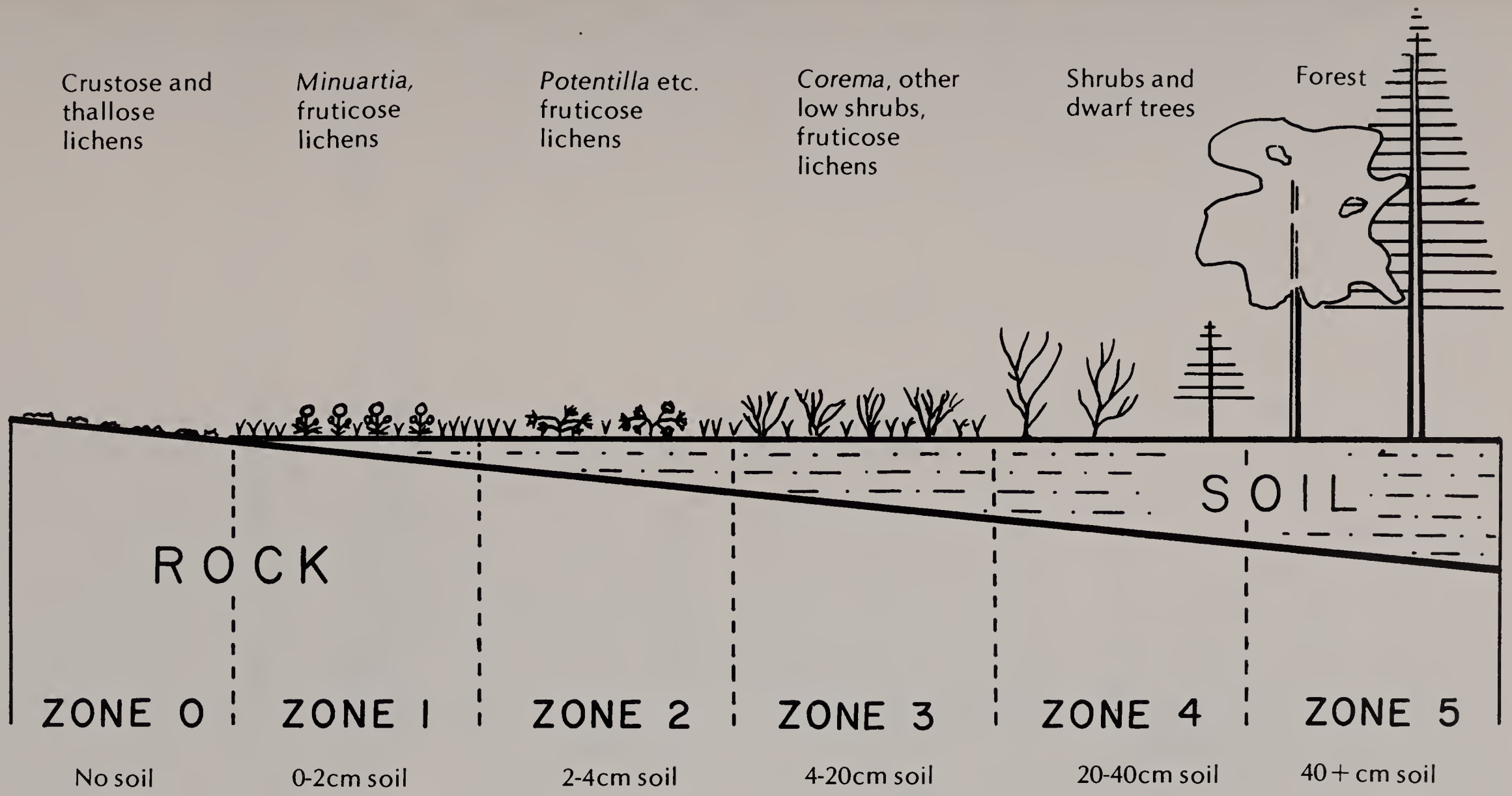

Fig 2. Diagram of soil-plant zones on the Kidston Lake barrens.

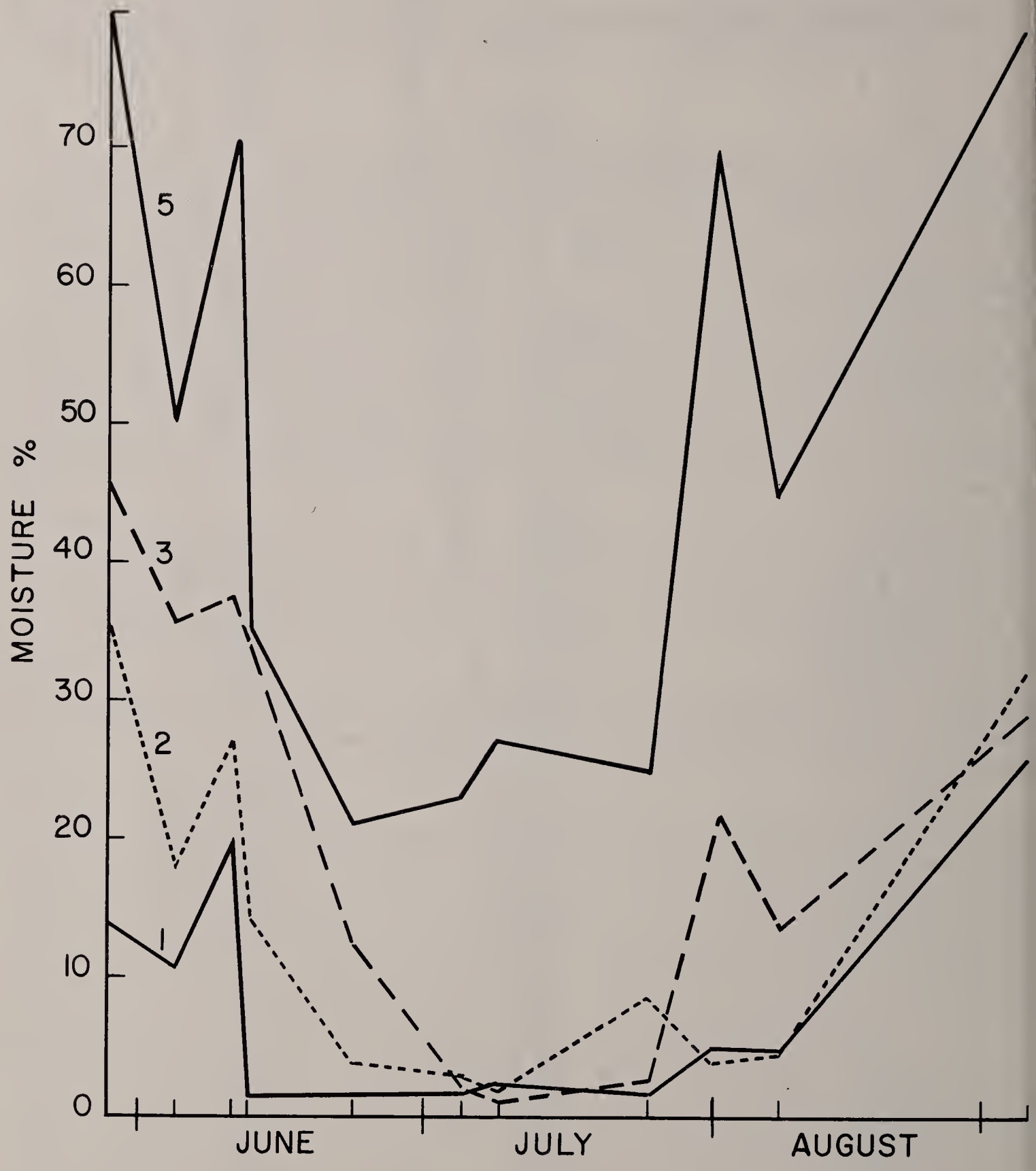

Fig 3. Soil moisture in soil-plant zones 1, 2, 3 and 5 during summer 1975.

Discussion

It seems clear that *Minuartia* grows on the Kidston and other barrens because these are 'open', low-competition habitats and, as in the case of other arctic-alpines, competition from other plants, especially by shading, eliminates individuals. Observations on small seedlings for a few weeks following germination confirm this. There was abundant germination in September and October 1975 in Zones 1, 2, and 3 but most seedlings among the taller lichens and herbs grew weakly and etiolated and the majority died within a few weeks. This extreme intolerance of shading would appear to be the mechanism which keeps the sandwort confined to Zone 1.

At one time we were considering whether some peculiarities of the chemical composition of the coarse, grey granite (a biotite-granodiorite) on which the *Minuartia* grows might be responsible for its restriction to barrens in the same way that some species are confined to serpentine or calamine outcrops. However, while there is really no published data commenting on granite composition and associated floras, the analyses in Table 1 do not show any obvious peculiarities and the idea was dropped in favor of other interpretations.

The topography is probably more significant than the chemical nature of the rock in permitting the survival of *Minuartia*. The barren is formed on an undulating, glacially planed surface with areas of smooth uncracked granite exposed between more broken, blocky areas and hollows. There are a few glacial erratics lying on this granite pavement but till deposits are absent. The *Minuartia* grows on the smooth, uncracked pavement while the valleys and more broken areas support bushes and trees. The topography controls the soil depth and this in turn controls the type of vegetation; the islands of exposed, smooth granite support the *Minuartia* populations. Surrounding these are more or less level areas of granite supporting a bush vegetation mainly of huckleberry (*Gaylussacia baccata*) and lambkill (*Kalmia angustifolia*), while the hollows and broken areas of rock provide rooting opportunities for trees and a low-grade red maple, birch, black spruce woodland covers these areas.

The exposed rock is never perfectly level and slight depressions accumulate a soil of up to a few centimetres in depth. The soil is composed of coarse quartz crystals which have been weathered out of the granite surface and washed into the depressions, together with a black, amorphous humus presumably largely derived from the decay of the abundant lichens. This thin soil has too shallow a rooting depth to allow the growth of many vascular plants, but a thick mat of lichens, especially *Cladonia boryi*, dominates the areas. *Minuartia*, a very few other herbs and dwarf specimens of shrubs such as *Corema* and blueberry (*Vaccinium angustifolium*) can survive on these shallow soils but not larger bushes or trees. The soil zones and associated vegetation are shown in diagrammatic form in Figure 2.

While the original glacially formed topography was responsible for setting up the mosaic of smooth, raised granite areas interspersed with more broken rock and depressions there has to be some mechanism which has prevented the ecological succession from establishing a spruce-maple forest over the whole barren and thus wiping out the *Minuartia*. Fire and drought are the presumed agents and our thinking at the moment tends to give the greater role to drought. Observations in previous years had indicated that the shallow soils of Zones 1 and 2 dried out rapidly during dry periods both because their shallowness prevented any appreciable water storage in the humus and because they were exposed to the full sun and wind. This is confirmed by the results of moisture measurements shown in Figure 3 which shows that the soil in Zone 1 dried out very rapidly with the onset of drought conditions in May and remained at a low moisture level through the summer. Zones 2 and 3 dried out less rapidly and suffered a shorter period of low moisture content, while soil containing a high humus content shaded by trees did not dry out sufficiently to really subject Zone 5 vegetation to a severe water stress. The capacity of Zones 1, 2, and

Table I: Soil, plant ash and rock analyses (soil and plant ash analysed by qualitative emission spectrograph, rock data from T.E. Smith, 1970)

Kidston barren soil	Big Tupper barren soil	*Minuartia*, Kidston plant ash	Biotite-granodiorite Spryfield	
		1%	%	
Aluminium	Aluminium	Aluminium	SiO_2	69.47
Potassium	Potassium	Calcium	TiO_2	0.59
Silica	Silica	Potassium	Al_2O_3	15.35
Sodium	Sodium	Silica	Fe_2O_3	2.89
		Sodium	MnO	0.09
		100 ppm - 1%		
Calcium	Calcium	Cobalt	MgO	1.06
Cobalt	Cobalt	Copper	CaO	2.21
Iron	Iron	Iron	Na_2O	3.17
Magnesium	Magnesium	Lead	K_2O	4.04
Manganese	Manganese	Magnesium	P_2O_5	0.19
Strontium	Strontium	Manganese	H_2O	0.32
Titanium	Titanium	Nickel		
Vanadium	Vanadium	Strontium		
		Titanium		
		Vanadium		
		Zinc		
		100ppm		
Beryllium	Chromium	Chromium		
Chromium	Copper	Silver		
Copper	Lead	Tin		
Lead	Nickel	Zirconium		
Nickel	Silver			
Silver	Tin			
Tin	Zirconium			
Zirconium				

3 to hold water is additionally lessened by the presence of coarse quartz crystals weathered from the granite; Zone 1 soil contains about 90% quartz dryweight. It should be pointed out, however, that 1975, the year during which soil moisture levels were measured, did not have anywhere near average summer weather, this can be seen by referring to Table II showing the April-September precipitation, mean maximum monthly temperature, and insolation. Rainfall was far below normal levels, average temperatures were near normal with a few very hot days, and there was much more sun in June than usual. The effect of this on the vegetation

was quite dramatic. By midsummer all the *Minuartia* plants were dead in contrast to the previous few years when the larger plants had survived as rosettes over the summer and bloomed again in the autumn and the following spring. In addition the plants of *Corema, Danthonia, Potentilla, Carex,* and *Picea* in Zones 2 and 3 were either killed or severely damagaed.

The 1975 drought affected the *Minuartia* population in a genetic sense since every individual in 1976 was recruited from seed (which germinated abundantly August-October 1975). More usually the spring population consists of a mixture of older plants which have survived for 1 or more years and seedlings which have overwintered from the previous autumn. The more southern plant *M. groenlandica* var. *glabra* is characterized, by its winter annual habit, recruitment being entirely from seed each year. The arctic-alpine var. *groenlandica* is a moderately long-lived perennial. Weaver (1970) uses length of life cycle as the prime separating factor in his key to distinguish the 2 plants, but it can be seen that the Kidston Barren plants possess a flexible life style intermediate between the 2 currently recognized taxa.

The drought had the effect of lessening competition in Zone 2 and some of the *Minuartia* seedlings which had germinated in Zone 2 sites in late 1975 were observed to flower in spring of 1976. This is quite contrary to observations of other years. Thus, drought has the effect of preventing the normal ecologic succession by killing herbs, shrubs, and tree seedlings and we consider this the prime cause of the persistence of the barrens and the suitable habitat for *Minuartia*.

Fire swept over part of the barren in spring 1977 and it was interesting to observe the contrasting ecological effect of this compared to drought. The fire destroyed the above-ground parts of shrubs and trees in Zones 4 and 5 but was unable to spread over Zones 1, 2 and 3 and apparently had no effect on them. The *Minuartia* bloomed as normal but was not able to spread any further as a result of the fire. Regeneration from stumps and underground shoots led to a vigorous regrowth in the burnt zones by the end of the growing season. Thus, fire does not create open areas available to *Minuartia* although it does alter the species composition of the scrub and forest. Fire is now frequent in the area because of its proximity to the suburb at Spryfield. It is difficult to assess the role of naturally occurring fire in the area, but the Kidston Lake Barren is in the foggy Atlantic Coast region where the high rainfall and humidity and low incidence at lightning strikes leads to a low level of natural fires. Thus, we consider that the Kidston Barren is an ancient and very stable topographic-edaphic unit arising as a result of the geological accident of massive rock left uncovered by glacial debris and hence not accessible to tree growth. We regarded the area as a rock barren. Although it is now regularly burnt as a result of human action

Table II: Rainfall, Temperature, and Insolation records abstracted from Annual Meteorological Summary 1975, Shearwater A Station (Environment Canada, 1976).

	Monthly Mean					
	Precipitation mm		Max Temperature		Insolation hours	
	1975	Normal	1975	Normal	1975	Normal
April	86.7	105.4	6.6	8.1	138.1	176.0
May	66.3	109.5	13.2	13.6	222.3	217.1
June	65.3	85.1	19.4	18.3	276.6	216.7
July	36.2	96.0	22.8	21.9	208.8	219.8
August	47.1	97.0	21.6	22.0	213.8	214.2
September	73.3	94.2	19.1	18.9	170.4	170.9

and is hence called a fire barren we regard the term as misleading from the point of view of the ecology of the *Minuartia*.

The habitat of *Minuartia* in Nova Scotia bears a striking physical resemblance to the granite barrens on the fall line between the piedmont and the coastal plain in North Carolina described by Oostings and Anderson (1939). Their description of more or less level areas of exposed granite with depressions accumulating a shallow soil in which species are zoned according to soil depth is exactly parallel to the Nova Scotian situation, although the mechanism producing the exposed granite is different since North Carolina was not glaciated. However, almost no species, apart from *Minuartia* (of which there are two species in North Carolina, see comment by Weaver 1970), are common to the 2 areas. It seems that similar topographic conditions, usually but not always exposed granite, from Nova Scotia to Georgia have acted as refugia for the shorter-lived, more southern-oriented series of populations. The maintenance of these conditions is obviously vital to the persistence of the species.

It is possible to give a conjectural reconstruction of the history of *M. groenlandica* in Nova Scotia from what is known of general postglacial history and the species habitat requirements. Because Nova Scotia was entirely covered by ice at the peak of the last glaciation, we can presume that *Minuartia* survived somewhere to the south or possibly on the offshore banks exposed by the lowered sea level. Ogden (1959) records *Caryophyllaceous* pollen at several levels in a late-glacial pollen sequence from Martha's Vineyard, Massachusetts. This pollen cannot be positively identified to species but in the context of the associated flora is probably derived from *M. groenlandica* since the earlier parts of the sequence probably represent tundra vegetation.

With the retreat of ice from Nova Scotia, a tundra vegetation invaded and *Minuartia groenlandica* was presumably an abundant plant during this period. This seems a safe assumption although no *Minuartia* pollen has been reported from palynological research in the province. With the rapid spread after about 9000 BP of spruce, birch, other trees and shrubs into the province, the open, low-competition habitats necessary for a heliophilous plant would become restricted in area and the quantity of *Minuartia* would have fallen drastically. Eventually only certain rock areas with very shallow soils and sufficiently uncracked that tree roots could not penetrate, would support the species. These areas, the *Minuartia* refugia, have probably been stable for the greater part of the time since trees arrived — maybe the past 9000 years or more. It seems unlikely that there has been any genetic interchange between these populations since the arrival of trees. During this time of isolation, the possibly genetically variable immigrant population would have become closely adapted to the climatic-edaphic conditions of each site resulting in the annual-perennial form of the species so exquisitely tuned to the Nova Scotian climate but so puzzling to herbarium taxonomists familiar with plants from more reliable climates to the north or south of the province.

Our observations indicate that the presence of *Minuartia* in the province is the product of its life cycle, the presence of unusual topographic conditions, and the migrations which occurred following the end of the last glaciation. The ability to produce a large crop of seeds every year and, under certain conditions, maintain its populations entirely from seeds, immediately marks it as having a different life cycle from all the other Nova Scotian arctic-alpines and indeed from most arctic plants, in which the annual habit is much less common than the perennial strategy. The germination of seeds over a period of months is undoubtedly of survival value. Recently germinated seedlings have been observed in August, September, October, and May — this spread of emergence allows the species to survive even if the plants from one particular month are wiped out by some climatic viscissitude. Growth can be rapid and some seedlings which had germinated in late August or early

September 1975 were found to have an open flower on 1 October. There is thus an approach to an ephemeral growth pattern, although the seedlings produce the majority of their flowers in the spring hence being more correctly regarded as winter annuals.

Not all plants necessarily die after the spring flowering, their fate depends on the succeeding summer which in Nova Scotia can vary radically from year to year. More often there is sufficient rain during the summer to allow some of the plants well established in the deeper soils of Zone 1 to survive and flower again, possibly for several years in succession. These plants are readily recognized in the spring by the presence of dead inflorescences and a better developed cushion of basal vegetative shoots. It is the presence of these semi-perennial plants and various metric characteristics which caused Fernald (1919) to write about Macoun's specimens: "the plant in stature and habit is perplexingly transitional to the boreal *Arenaria groenlandica,* being usually more tufted and lower than in *A. glabra* but with the very bushy habit of the latter and with pedicels intermediate in length, and petals shorter than in most arctic-alpine plants." The point to make here is not so much that the Nova Scotian plants are "perplexingly transitional" between two extremes, because these two extreme 'species' can be regarded as mere constructs of the human mind; what we wish to draw attention to is that the Nova Scotian plants are physiologically and genetically adapted to the climatic conditions prevailing at the site. The Nova Scotian climate is intermediate between the certain dampness of the arctic and the certain summer drought of the southern United States, and the flexible life cycle and intermediate morphology of the Nova Scotian plants is clearly adaptive for the uncertainties of the local summers. The populations clearly fall into the concept of ecotype originated by Turesson and the chain of populations from cool-damp to hot-dry conditions could well turn out to be a cline.

Now that we know more about the habitat requirements of *Minuartia groenlandica*, we can sensibly search other parts of Nova Scotia for it. Looking back on the history of its discovery in Nova Scotia we can see that Macoun's cryptic 'Rocky ground, North West Arm' must have misled people since it carries the implication that the plants grew on rocks alongside the seashore. This, and the low state of botany in the province was responsible for the 60-year gap between the first two collections. We are now of the opinion that Macoun was most likely on the Kidston Lake barrens when he and Burgess discovered the *Minuartia*. The Northwest Arm is visible from the site, it is certainly rocky and nearby is the Rocking Stone, a large granite, glacial erratic which is a local curiosity and would certainly be an obligatory trip for any visiting geologist of that era. The barrens are only a few hundred meters from the Rocking Stone.

Since there are extensive areas of rock barren in Nova Scotia, it seems highly probable that more populations of *Minuartia* remain to be discovered. The species is unfamiliar to the majority of people, and being small is easily overlooked or confused with other plants, e.g. *Sagina nodosa*. The areas marked as granite on Figure 1 give an exaggerated indication of the distribution of potential sites, although not all granite outcrops are topographically suitable. However, it is obvious that there is great potential, particularly in SW Nova Scotia although Cape Breton cannot be dismissed since there are many lichen barrens, especially in the Cape Breton Highlands. Even the distribution of granite does not define the potential sites since the locality near Blue Rocks is non-granitic.

Conclusions

Minuartia groenlandica is adapted by its annual or perennial life cycle to survive in either arctic-alpine or lowland habitats, but only the latter occur in Nova Scotia. It migrated into the province during the tundra phase following the last glaciation and has since become confined to a limited number of open habitats. These are

mainly on granite exposures, where the essential open habitat has been available continuously since trees migrated into the province. It differs from the other arctic-alpines of the province in its ability to survive drought by means of the seed phase, and may be much more common than our present information indicates.

Acknowledgements

We wish to thank J. MacNeill for notes on the various ways of subdividing Arenaria s.l., also W.S.G. Maass for the identification of lichens, M. Case for help with soil analysis, D. Patriquin for tests of nitrogen-fixing ability, and G.D. Lutwick of the Nova Scotia Research Foundation Corporation for the emission spectrography. D.B. Clark gave useful geological information..

References

Environment Canada. 1976. *Atmospheric Environment, Annual Meteorological Summary 1975: Halifax-Dartmouth, N.S. (Shearwater 'A').* Information Canada.

Fernald, M.L. 1919. The unity of the genus *Arenaria, Rhodora,* 21: 1-22.

Holmgren, P.K. and **Keuken, W.** 1974. *Index Herbariorum.* Part I. *The Herbaria of the World.* Utrecht, Netherlands.

Hulten, E. 1964. Remarkable range extension for *Minuartia groenlandica* (Retz.) Ostenf. *Sven. Bot. Tidskr.* 58: 432-435.

Komarov, V.L. et al. (ed.) 1934-1964. *Flora S.S.S.R.* Leningrad and Moscow.

Macoun, J. 1886. *Catalogue of Canadian Plants.* Part III. Dawson Brothers, Montreal.

Ogden, J.G. 1959. A late-glacial pollen sequence from Martha's Vineyard, Massachusetts. *Am. J. Sci.* 257: 366-381.

Oostings, H.J. and **Anderson, L.E.** 1939. Plant succession on granite rocks in eastern North Carolina. *Bot. Gaz.* 100: 750-768.

Radford, A.E., Ahles, H.E., and **Bell, C.R.** 1968. *Manual of the Vascular Flora of the Carolinas.* University of North Carolina Press, Chapel Hill.

Roland, A.E. and **Smith, E.C.** 1969. The flora of Nova Scotia. Part II. The dicotyledons. *Proc. N.S. Inst. Sci.* 26: 277-743.

Shetler, S.G. and **Skog, L.E.** 1978. *A Provisional Checklist for Flora North America (revised).* Monographs in Systematic Botany, 1. Missouri Botanical Garden.

Smith, T.E. 1970. The geochemistry of the granitic rocks of Halifax County, Nova Scotia. *Can. J. Earth Sci.* 11: 650-657.

Tutin, T.G. et al. (ed.) 1964-. *Flora Europaea.* Cambridge Univeristy Press, London.

Weaver, R.E. Jr. 1970. The Arenarias of the Southeastern granitic flat-rocks. *Bul. Torrey Bot. Club,* 97: 40-52.

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STUDIES ON THE TAXONOMY AND DISTRIBUTION OF *SPHAGNUM* VIII. THE FRUITING OF *SPHAGNUM PYLAESII* IN NOVA SCOTIA AND ITS CHROMOSOME NUMBER*

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In an earlier paper we reported on chromosome numbers of some North American species of *Sphagnum* (Maass & Harvey 1973), but were not able to include either *S. pylaesii* Brid. or *S. cyclophyllum* Sull. et Lesq., both of which are currently regarded as members of Sect. *Subsecunda* (subgenus *Isocladus).* These two species differ from all other *Sphagna* in the morphology of their sporophytes, and they were at one time segregated as the genus *Hemitheca* Lindb. (Andrews 1960, 1961). Their gametophytes also have unique properties, such as the presence of membrane pleats, the almost complete lack of pores in the hyaline cells of *S. pylaesii,* and the absence of branches and branch leaves from *S. cyclophyllum.* For these reasons and because of ambiguities in their phylogenetic position (expressed e.g. by Andrews 1912; see also Eddy 1977), their chromosomal relationship to other species of *Sphagnum* was of interest.

Hitherto all species of *Sphagnum* studied have had chromosome numbers of n=19 or n=38 (see Maass & Harvey 1973 for reference). Sorsa (1956) speculated that the presently known *Sphagna* with the basic chromosome number 19 are possibly derived from ancestors with a lower number, such as n=9 (reinterpreted from his figure "4 + 1", p. 13 loc. cit.). Another possibility is that the number 19 was derived from an ancestral n=10 by polyploidy with fragmentation of one chromosome to form the so-called m-bodies. We thought that a study of the chromosomes of the relatively isolated *S. pylaesii-S. cyclophyllum* group might represent an opportunity to find such an ancestral number.

Although fruiting is extremely rare in these species (Andrews 1960; Maass 1966) we have succeeded in obtaining fruiting sporophytes of *S. pylaesii* in three localities: 1. Halifax County between Purcell's Cove and York Redoubt in a pond by the main highway near Devil's Hill Road, UTM grid reference ME 553387; 2. Shelburne County in a large bog between Jordan Falls and Sable River about 0.5 km north from highway 103, LD 247555; 3. Shelburne County in the Clyde River Valley 6.5 km from highway 3, in bog pools growing mixed with *S. cyclophyllum,* KD 990555. All of the

*NRCC 17155

fruiting material belongs to the heavily branched (i.e. fully developed) and blackish brown tinted form as were the specimens reported from New Jersey (Andrews 1961). Voucher specimens have been deposited in the herbarium of Dalhousie University (DAL). So far *S. cyclophyllum* has not been found fruiting in Nova Scotia, although its gametophytes have been collected from a few localities newly discovered for Canada in 1973 and 1974 (Maass et al., unpublished).

A meiotic count of n=19 (Fig 1) was established. This confirms the basic number observed in *Sphagnum* and fails to support speculations based on numbers lower than 19. Although *S. cyclophyllum* remains to be examined, a critical and perhaps rather archaic member of the genus has been eliminated as a candidate for a more primitive chromosome number in the genus *Sphagnum*. Another interesting member of the genus to be studied for its chromosomes is *S. sericeum* C. Muell. endemic to Indomalaysia (the only member of subgenus *Homophylla)*. It differs from all other species by the presence of a characteristic leaf apex and is now being regarded as the most primitive *Sphagnum* by Eddy (1977).

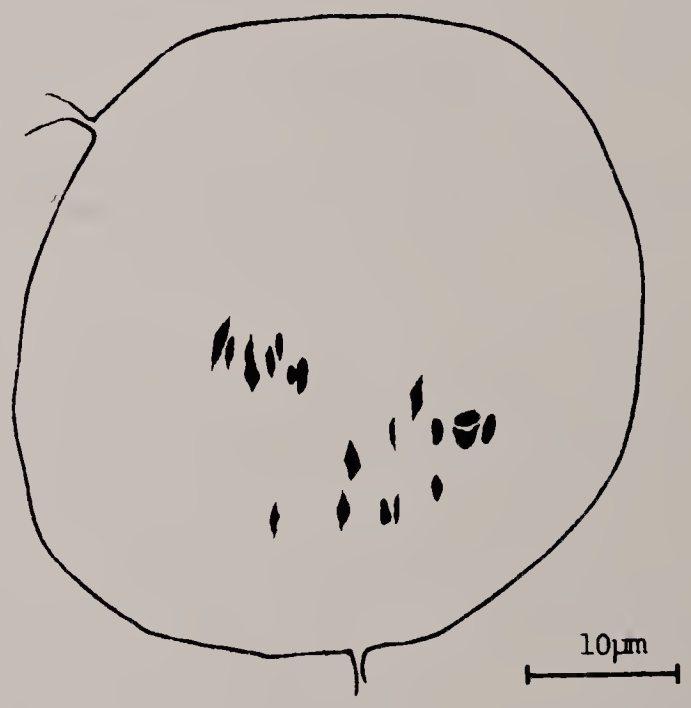

Fig 1. Drawing of metaphase 1 of meiosis in the sporophyte of *Sphagnum pylaesii* showing n=19.

References

Andrews, A.L. 1912. Notes on North American *Sphagnum* III. *Bryologist* 15: 63 - 66 and 70 - 74.

Andrews, A.L. 1960. Notes on North American *Sphagnum* XII. *Sphagnum cyclophyllum. Bryologist* 63: 229 - 234.

Andrews, A.L. 1961. Notes on North American *Sphagnum* XIII. *Sphagnum pylaesii. Bryologist* 64: 208 - 214.

Eddy, A. 1971. Sphagnales of Tropical Asia. Bull. Brit. Mus. Nat. Hist. (Bot.) 5: 359 - 445.

Maass, W.S.G. 1966. Untersuchungen über die Taxomomie und Vertreitung von *Sphagnum* VI. *Sphagnum pylaesii* Brid. und das boreo-atlantische Florenelement unter den Torfmoosen in Südamerika. *Nova Hedwigia* 12: 81 - 105.

Maass, W.S.G. and **Harvey, M.J.** 1973. Studies on the taxonomy and distribution of *Sphagnum* VII. Chromosome numbers in *Sphagnum. Nova Hedwigia* 24: 193 - 205.

Sorsa, V. 1956. The quadripole spindle and the change of orientation of the chromosome in meiosis of *Sphagnum. Ann. Acad. Sci. Fenn.* Ser. A4, 33: 5 - 64.

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A MECHANICAL SEARCH AND RETRIEVAL SYSTEM FOR MYCOTOXINS[1]

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Mycotox is a list of fungi that have been reported to produce toxic metabolites, or metabolites closely related chemically to such toxins. It is intended for use by mycologists and chemists and assumes a working knowledge of mycology and/or natural product chemistry by its users. It has been written onto a computer file and can, therefore, be searched automatically. The data base will be augmented as new information is published.

Introduction

In the last 2 decades, it has become clear that the toxic metabolic products of fungi have wider consequences than occasional cases of *Amanita* poisoning (Weiland & Weiland 1972) or outbreaks of St. Anthony's fire (Gröger 1972). For example, it is now very likely that a group of diseases of sheep and cattle, characterised by photosensitivity, involves a fungal vector (Atherton et al 1974). Similarly, the production of aflatoxins by *Aspergillus flavus* (Detroy et al 1971) is probably a factor in diseases of man and other animals (Gurto et al 1978). There are several other well-documented conditions involving fungi that have been described. The epidemiological characteristic of, for example, contaminated grain, has led the Food and Agricultural Organization of the United Nations to inaugurate laboratories in several parts of the world which will monitor shipments of food-stuffs for mycotoxins (FAO Food Control 1977). Thus, shipments of food-stuffs from Canada will be the object of analyses by these FAO laboratories. For this reason, as well as that of aspiring to export produce of the highest quality, it is prudent for those responsible for quality control of Canadian food-stuffs to have information about mycotoxins readily available. We have been concerned with toxic fungal metabolites for the last 30 years, and have kept a close watch on the literature. We felt that the cumulative results of this reading might be valuable to other workers, and we have written some of this information onto a computer file from which it can easily be retrieved. This paper describes the information written onto the file and the method of search.

[1] Issued as NRCC No. 16919

Organization of the File Mycotox

The file consists of 4 columns. The information in each column is: column 1 a list of fungal binomial names; column 2 accession numbers (where applicable) whence the fungi may be obtained; column 3 a list of mycotoxin names; column 4 a list of references. The file is meant to be read horizontally, that is, the name of the fungus, the culture collection from which it is available, the mycotoxin it produces, and one or more references to the original work that describes the occurrence of the mycotoxin. For the purpose of this paper, however, each of the 4 lists will be described in turn.

List of Fungi

Species names are given in full without authorities. Where there exist synonyms for systematic names, the name adopted in the reference given is used. If the same culture of an organism produces 2 or more metabolites, the organism appears 2 or more times in the list. In a few instances, fungi that do not produce toxic metabolites, but which are difficult to differentiate from related species that do, are entered. In particular, such cases are entered where a chemical taxonomic differentiation is possible. A few Actinomycetes are included that produce toxic metabolites closely related to common fungal metabolites.

List of Culture Collections

Where the mycotoxin producing strain of the fungus reported in the reference quoted can be obtained from a public culture collection, either freely or for a fee, the name of the culture collection is given and also the accession number of the isolate. The name of the culture collection is abbreviated, but the search programing allows the enquirer to request a translation of the abbreviation and also the address of the collection. In a few cases a star appears after the accession number. This means that an isolate of this species that produces the particular mycotoxin is in our collection and freely available to Canadian workers.

List of Mycotoxin Names

The choice of mycotoxins in this list was governed by the following criteria:

(a) Each metabolite must be chemically characterised, i.e. enough physical and chemical data must be given in the reference to permit repetition. Thus, all ill defined biological polymers, fleetingly stable biosynthetic intermediates, and metabolites produced by introducing abnormal substrates into fermentations are omitted. However, some artifacts of isolation procedures are admitted.

(b) All the compounds in the list (with the exception of a few Actinomycetes metabolites—see above) are produced by fungi. This restriction results in the omission of several phytoalexins and lichen constituents that may well be of fungal origin.

(c) All listed compounds inhibit growth or some other primary function of a living organism, e.g. respiration. The selection rule has been that if a metabolite is poisonous to one species, e.g. a bacterium, it is likely to be toxic to all. Metabolites that merely affect the catalysis of a particular reaction by an isolated enzyme are not included, but on the other hand metabolites that have not been shown to be toxic but that are related to toxic compounds (whether of fungal origin or not) are included.

Generally speaking, names given to mycotoxins by their discoverers are quoted. When no name is given but the systematic (I.U.P.A.C.) nomenclature used, this is given if the name is less than 35 characters long. Sometimes the systematic name is slightly abbreviated, where the stem can be used to abstract all of one group of toxins from the list. If the systematic name is longer than 35 characters, the

molecular formula is given and the elements are quoted in accordance with *Chemical Abstracts* usage. To some extent family names, e.g. trichothecene, are also given in addition to the name used by authors. This is to help in the abstraction of all members of a group. This device is also used when the chemical structure of the metabolite is unknown, but sufficient of its chemistry is known to allow it to be classified in a well-known group.

List of References

References have been chosen with the following order of priority in mind. Review references are quoted if they exist. In the absence of a review, the original full report of the production of a mycotoxin is given. Preliminary reports have been avoided as far as possible as these sometimes refer to fictitious work. We have tried to quote papers that give full experimental details, but workers should not fail to write for fuller information to the authors (we wish them luck!!). Most of the references contain toxicological data, but not necessarily those of the most important studies on this aspect of the subject. No author's names are given, the names of journals are drastically abbreviated and years of publication are usually (where there is a volume number) omitted as superfluous. The numbers after the journal abbreviation are always the volume number and the first page of the paper. Most users of the file will be able to guess the meaning of the abbreviations, but if they are in doubt the system has been designed to allow enquirers to ask for a translation. Usually only one reference is given, because we wish to leave room on the line for other important references that may occur in the future. In several cases we have a large number of references to a mycotoxin(s) that has not been the subject of a review article. In such cases we are willing to supply a list to colleagues in the field.

Method of Searching the Mycotox File

Before any use of the file can be made, it is necessary to obtain a user number from the Computer Center, Dalhousie University, Halifax, Nova Scotia, B3H 4J3. Write to this address and ask for a user number for searching the mycotox file. Having a number, one can then find a computer terminal, e.g. a telex machine with an acoustic coupler and a telephone. If the terminal is set to 300 baud one then dials the number 902-424-8800 (if 110 baud, 902-424-6480) and when a high pitched buzz is heard in the telephone the receiver is placed (the right way round) on the acoustic coupler. The carriage return key is pressed and the computer responds:

YEAR/MONTH/DAY. HOUR, MINUTE, SECOND.
DALHOUSIE UNIVERSITY NOS 1.2-446 (K) NOS 1.2-446
USER NUMBER:

The user number given by the computer center is now typed in followed by a comma, a space, and a carriage return, after which the computer responds:

TERMINAL: X, TTY
RECOVER/SYSTEM

In the vast majority of cases the user now types **mycotox**. If however there has been a fault in the telephone transmission which resulted in the connection being broken (for 5 min or less) one can type **Recover, X, TTY** where X is the integer given on the original connection after the word TERMINAL in most cases the computer responds:

NRC ATLANTIC REGIONAL LABORATORY
FUNGAL TOXIN REFERENCES

TYPE HELP OR ENTER A COMMAND
C?

It is now possible to start the search and retrieval procedure, and for the majority of enquiries an entry **List** followed by the name of a fungus or a mycotoxin and a carriage return will print all the entries on the file in which the name of the fungus or mycotoxin occurs. Lifting the telephone off the acoustic coupler then terminates the session.

It is possible, however, to use the system to acquire further information, and to obtain a more polished printed record of the search. The means of doing these tasks are discussed in the next sections.

Format of the Printed Record

There are 4 commands that are used to control the format of the printed output. These are: Narrow, Wide, Limit and Relist.

The commands **Narrow** and **Wide** govern the width (i.e. the number of characters) on a printed line. The one to use depends on the computer terminal in use. The **Wide** command permits the user to print the information available on the file pertaining to 1 fungus or 1 mycotoxin on 1 line of print. Such a terminal must have a platten at least 126 characters wide. The **Narrow** command prints the same information on 2 lines and must be used when the teminal prints lines of 72 or fewer characters wide. The system normally assumes that the terminal in use is less than 72 characters wide. If on searching the file in response to the **List** command more than 5 entries are found, the first 5 lines will be printed and then the user will be asked if the information they require has been printed or whether they wish the remaining information to be divulged. The purpose of this format is to reduce to a minimum telephone line charges. However, if all the data found in the search are needed, the printed results of the search become fragmented. Thus, the limit of 5 lines can be overcome by the use of the **Limit** command in the form **Limit X** where X is an integer. If X is chosen as the total number of lines found in the search, the record can now be printed out continously, without using further computer time, by entering the **Relist** command (see Table I). The **Relist** command can be used any number of times, to e.g. obtain copies of the search record, or to obtain a copy of the sorted file if a recovery operation has been successfully completed.

Searching Mycotox for Information

Four commands are used for this purpose. By far the most important is **List.** An example of the use of this command in its simplest form has been given, and a typical response by the computer is shown in Table 1. It should be noted that a space is required between the word **List** and the word, or part of a word, for which a search is done. It is possible, however, to use the list command, to search the file in greater or lesser degrees of discrimination. For example, the Command **List Aspergillus** will result in the selection of all the genus *Aspergillus* that are known to produce toxic metabolites. Similarly the command **List Aspergillus flavus** will result in a list of all the mycotoxins known to be produced by *A. flavus*. Finally the **List** command can be used in the form **List Aspergillus flavus . . .afla** and this will now reduce the printed record to only those isolates of *Aspergillus flavus* that produce a mycotoxin having the sequence of letters **afla** in its name, i.e. it prints (among other things) all entries on the file that record the production of aflatoxin by *A. flavus*. It follows that complete words are not required by the **List** command, and this is a useful attribute in a chemical sense. Obviously **List acid** will result in the selection of all the acids on the file where the word acid appears in the name. Thus, polyporic acid will be selected but penicillin will not. However, the command can be used in a more sophisticated sense chemically, e.g. **List ol** resulting in the selection (among other things) of

Table I. Typical enquiry session illustrating format and reformat of the search results.

```
                    ***NRC ATLANTIC REGIONAL LABORATORY***
                          FUNGAL TOXIN REFERENCES

        TYPE 'HELP' OR ENTER A COMMAND
C? LIST HELMINTHOSPOR
    COCHLIOBOLUS SATIVUS                    IMI 125851
      9-HYDROXYPREHELMINTHOSPOROL                       J 1970 686
    COCHLIOBOLUS SATIVUS                    IMI 125851
      PREHELMINTHOSPOROL                                J 1970 686
    HELMINTHOSPORIUM DEMATIOIDEUM           O
      CYTOCHALASINS                                     J 1969 923
    HELMINTHOSPORIUM DEMATIOIDEUM           O
      CYTOCHALASIN F                                    J (U) 1972 148
    HELMINTHOSPORIUM DEMATIOIDEUM           IMI74812
      C29H35N05                                         CH 66 9972E      CR
MORE LINES TO COME; TYPE 'END' TO STOP HERE?
    HELMINTHOSPORIUM HEVEAE                 IMI 80137
      HEVEADRIDE                                        J 1973 194
    HELMINTHOSPORIUM LEERSII                O
      LUTEOLEERSIN                                      BJ 32 449
    HELMINTHOSPORIUM LEERSII                O
      ALBOLEERSIN                                       BJ 32 449
    HELMINTHOSPORIUM MONOCERAS              IMI 125855
      MONOCERIN                                         J 1970 2598
    HELMINTHOSPORIUM SACCHARI               O
      HELMINTHOSPOROSIDE                                JBC 246 4350:
                                                        PH 61 691:66 423
    HELMINTHOSPORIUM SATIVUM                O
      HELMINTHSPOROL                                    CH 65 19273A
    MORE LINES TO COME; TYPE 'END' TO STOP  HERE? END                    CR
C? LIMIT 20                                                              CR
C? RELIST                                                                CR
    COCHLIOBULUS SATIVUS                    IMI 125851
      9-HYDROXYPREHELMINTHOSPOROL                       J 1970 686
    COCHLIOBOLUS SATIVUS                    IMI 125851
      PREHELMINTHOSPOROL                                J 1970 686
    HELMINTHOSPORIUM DEMATIOIDEUM           O
      CYTOCHALASIN S                                    J 1969 923
    HELMINTHOSPORIUM DEMATIOIDEUM           O
      CYTOCHALASIN F                                    J (U) 1972 148
    HELMINTHOSPORIUM DEMATIOIDEUM           IMI74812
      C29H35NO5                                         CA 66 9972E
    HELMINTHOSPORIUM HEVEAE                 IMI 80137
      HEVEADRIDE                                        J 1973 194
    HELMINTHOSPORIUM LEERSII                O
      LUTEOLEERSIN                                      BJ 32 449
    HELMINTHOSPORIUM LEERSII                O
      ALBOLEERSIN                                       BJ 32 449
    HELMINTHOSPORIUM MONDCERAS              IMI 125855
      MONOCERIN                                         J 1970 2598
    HELMINTHOSPORIUM SACCHARI               O
      HELMINTHOSPOROSIDE                                JBC 246 4350:PH 61
                                                        691:66 423
MORE LINES TO COME; TYPE 'END' TO STOP HERE? END                         CR
    C?
```

alcohols and phenols. The most useful form of this facility is in selection on the basis of the stem of a systematic name, e.g. **List trichothec** will select from the file all the T2 type mycotoxins.

The second command to obtain information is the **Help** command. By the use of this command, most of the information given in this paper can be acquired. Its use for this purpose is likely to be expensive in telephone line charges from any but a local (i.e. Halifax) terminal. Rather, the command is designed as an amenity for a user who needs to prompt their memory while engaged in a search for information. The form of the command is **Help XXX** where XXX is another command, or if it is the name of a command that has been forgotten **Help index** which results in all the topics on which help is available to be printed.

The third command that provides information is the **Changes** command. It is intended to update the file on about a monthly basis. The information added will be that, we have culled from the literature as part of our normal reading, and also information that other users have found to be in error or omitted. By entering the command **Help changes,** the user will find out the last date that new information was entered on the file and also any other change in the amenities provided by the Computer Center to aid future searches.

Lastly the command **Abbrev**, in the form **Abbrev X** where X is an abbreviation used in the file, will result in the printing of a full translation of the abbreviation. Typical examples are given in Table 2. When the abbreviation is a journal name, the full title of the journal is printed; when it refers to a culture collection, the full name of the collection and its postal address is printed.

Disconnection from the System

As mentioned above, when an enquirer has finished a search of the file, the session can be terminated merely by replacing the telephone on its cradle. A better method is to respond to the system prompt C? by typing **End.** This is an improvement because the computer will disconnect the telephone and in addition it will provide useful information i.e. the cost of the computer session, for which the user will be charged by the Computer Center, and the length in hours of the session. This latter information is useful for checking telephone charges (Table 2).

Discussion

This search and retrieval system is essentially a "do it yourself" utility for the use of mycologists and natural product chemists. The user needs to know how to use a remote computer terminal, which amounts to an acquaintance with the use of a acoustic coupler for a telephone with a typewriter keyboard, and with the necessity of sending each line of typed information to the computer by means of the carriage return key. Beyond this the user needs to become acquainted with the commands described in this paper, and we have found that colleagues who have consented to act as guinea pigs have learned these quickly. Recently the system has been demonstrated publicly in Montreal and Winnipeg, and has performed faultlessly. It seems reasonable to extrapolate this result and to assume that a similar success will attend its use anywhere in Canada. About 200 searches of the file have been done so far, and the average cost of a single search is about $0.30. Using a terminal operating at 300 baud, the time of searches of about 10 lines output, is less than 1 minute. This assumes that no other enquires about abbreviations, or reformatting the output have been made. Thus, the total cost of an enquiry from Vancouver at the period of maximum telephone charges would be about $1.50. Such charges compare very favorably with all other mechanical search and retrieval systems, and we hope that this economy will make the system popular. As indicated in the description of the **Changes** command, it is possible for a user to contribute to the informa-

Table II. Illustration of the use of the "Abbrev" command to translate journal abbreviations or names and addresses of culture collections.

```
ABBREV N
C? N
        NATURE, LONDON
C? ABBREV IMI
   IMI
        Commonwealth Mycological Institute, Ferry Lane, Kew, England
C? END
NRGE001      LOG OFF          14.04.55.
NRGE001      SRU              3.981 UNITS.
CONNECTED          0.116 HOURS,
SESSION COST       0.560 DOLLARS.
```

tion in the file. At the moment, this must be done by mail. It is suggested that when a user finds an error or omission in the file, they send details (preferably on a postcard commonly used for reprint requests) to one of the authors at the Atlantic Regional Laboratory. The information will then be checked, and if it meets criteria stated in the first part of this paper, it will be incorporated in the following update of the file. If it does not meet these criteria, the reasons for its omission will be sent to the user.

Some minor additions to the information on each line are possible and we welcome suggestions. A little more chemical information could be given, e.g. molecular formulae and perhaps toxicological references. Correspondence on these matters should be addressed to the authors at the Atlantic Regional Laboratory. Readers interested in the computational devices used should send their enquiries to Mr. Evans at the Computer Center.

We regard the system not only as a useful tool to the busy practising mycologist who urgently needs to know if a fungus isolated from a toxic feed sample is a known producer of mycotoxins, but also as an experiment in a literature awareness facility, controlled and operated by research workers for their own benefit.

References

Atherton, L.G., Brewer, D., and **Taylor, A.** 1974. *Pithomyces chartarum:* a fungal parameter in the aetiology of some diseases of domestic animals. In: *Mycotoxins,* pp. 29-68. (Ed. I.F.H. Purchase). Elsevier, Amsterdam.

Detroy, R.W., Lillehoj, E.B., and **Ciegler, A.** 1971. Aflatoxin and related compounds. In: *Microbial Toxins,* Vol. VI, pp. 3-178. (Ed. A. Ciegler, S. Kadis, and S.J. Ajl.) Academic Press, New York.

Food and Agriculture Organization of the United Nations. 1977. Mycotoxin surveillance, a guideline. *FAO Food Control Series* No. 4.

Gröger, D. 1972. Ergot. In: **Microbial Toxins**, Vol. VIII, pp. 321-373. (Ed. S. Kadis, A. Ciegler, and S.J. Ajl). Academic Press, New York.

Gurto, H.L., Dahms, R.P., and **Paigen, B.** 1978. Metabolic activities of aflatoxins related to their mutagenicity. *Biochem. Biophys. Res. Commun.*, 81: 965-972.

Weiland, T., and **Wieland, O.** 1972. The toxic peptides of *Amanita* species. In: *Microbial Toxins.* Vol. VIII, pp. 249-280. (Ed. S. Kadis, A. Ciegler, and S.J. Ajl). Academic press, New York.

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A LITERATURE REVIEW OF THE FRESHWATER ALGAE OF THE CANADIAN ATLANTIC PROVINCES, QUEBEC, MAINE, AND NEW HAMPSHIRE

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A bibliography of the papers on freshwater algae of Prince Eward Island, Nova Scotia, New Brunswick, Quebec, Newfoundland, Maine, and New Hampshire is presented. All algal systematic papers from the earliest to July, 1977, are reviewed. Included is the first paper on Canadian freshwater phycology. A computer data base was generated from references up to August, 1975, as part of an algal study of the Dunk River, Prince Edward Island. A checklist (print-out), including more than 2500 taxa, was prepared from this data base under several headings, including: taxon—area—author—year; and taxa common to all areas. The checklist, together with the review, is presented for use as working tools for future related algal studies.

Introduction

In 1974 a study was conducted on the freshwater algae of the Dunk River, Prince Edward Island (Staker 1976) as part of an inter-disciplinary project initiated by the University of Prince Edward Island. A literature survey was prepared to provide background data on freshwater algal systematics from Prince Edward Island and surrounding provinces, New Brunswick, Nova Scotia, Quebec, and Newfoundland. The neighboring states of Maine and New Hamphire in the United States were also included as being part of a northeastern floristic area. A computer data base was prepared from the literature surveyed up to August 1975. Computer print-outs were prepared from the data base giving information under the following headings:

1. Taxon—area—author (by Division)
2. Checklist of algae
3. Number of species of algae by area
4. Taxa common to all areas
5. Taxa found only in one area
6. Literature cited.

Table I shows the various algal groups represented in the literature survey (August, 1975) for each province or state.

The computer print-outs (unpublished) are available from the Depository of Unpublished Data, National Science Library, National Research Council of Canada, Ottawa K1A 0S2.

The present review is based on 103 publications as used for preparing the computer data base and another 11 papers which have since appeared up to July, 1977. The review and computer print-outs are presented to provide a research aid for future algal studies of northeastern North America.

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Literature Review

Maine

The algae of Maine were discussed as early as 1888 by West, who listed 77 desmids, mainly from the Orono area. In the same state, West (1889, 1891) reported a total of 171 species. Three papers by Harvey (1888, 1889, 1892) treated the freshwater algae of the Orono-Penobscot River region of central Maine with over 100 taxa recorded. Taylor (1921) described both marine and freshwater forms of the algal flora of Mount Desert and some dozen or so algae are listed. One new species of *Spirogyra* was reported by Transeau *et al.* (1934) and Unger (1941) did a preliminary survey of the protzoa of Beaver Lake, near Salsbury Cove. Twenty-five of Unger's 92 genera of "invertebrates" are typically classified as algae by phycologists.

Four papers by Cooper (1939, 1940, 1942a, 1942b) and one by Cooper and Fuller (1945) described the general limnology of lakes in Maine. The principal algae, however, were identified to the generic level only. Wheldon (1943) has notes on algae collected and descriptions of new species from New England, including Maine, while Mackenthum, Keup, and Stewart (1968) discuss nutrients and the algae in Lake Sebasticook. The phytoplankton dominance, volumes and chlorophyll *a* concentrations were determined.

New Brunswick

In New Brunswick, the earliest studies appear to be those of Baxter (1903, 1905, 1907). He reported nearly 100 species of desmids and 139 forms *in toto* from the Miramichi River area. Habeeb and Drouet (1948) conducted a study in the Grand Falls area from June to mid-August, 1947, not including diatoms, desmids, *Chara, Oedogonium,* or *Mougeotia*. About 77 taxa were identified by Drouet. Hughes (1952) reported on the phytoplankton of 8 small lakes in the vicinity of Charlotte County. Limnetic phytoplankton identified in the study numbered 119. Klugh (1921) described a new blue-green genus, *Oligoclonium,* and 3 new species of blue-greens from the Chatham area. Geitler (1932) did not recognize this as a new genus but as a species of *Hydrocoleum*. In (1927), Klugh studied 18 sites in New Brunswick and Ontario, and reported on algal diversity and relative abundance. An *in vitro* study of microcrustacean eating habits was included.

Smith (1952) did a quantitative study of lakes in Charlotte County. The lakes were reported to be of Caledonian type with low productivity. Hughes identified the algae for Smith, finding 101 species, 40 of which were desmids. Besch *et al.* (1972) have studied the benthic diatoms in the Miramichi River, as indicators of mining pollution, recording 169 species. They found also that diatom communities could be used as reliable indicators of average pH conditions.

New Hampshire

Freshwater algal literature in New Hampshire dates back to Wood's paper (1869) on desmids from Saco Pond in the White Mountains. Hastings (1892) recorded 7 species of desmids, including notes. Cushman (1905) reported some 255 taxa of desmids from various lakes and ponds. Hoover (1937, 1938) conducted biological surveys of the Androscoggin, Saco, and Merrimack watersheds of New Hampshire. The plankton were identified by W.T. Edmondson and about 16 genera of phytoplankton were enumerated. Cole (1939) studied the plankton of the Connecticut River watershed. Identification was to the generic level only.

Wheldon (1942) recorded 83 species of algae with extensive notes, including some new species from ponds near New Durham. Blum (1943) described a new species, *Spirogyra echinospora,* from Hanover. Some freshwater algae from Louisiana and New Hampshire were studied by Flint (1948) including *Batrachospermum, Sirodotia,* and *Tuomeya*. Flint (1953) reported the presence of *Kyliniella,* a very rare form,

recorded only once previously and not since. The most comprehensive modern paper on algae in New Hampshire is that of Gruendling and Mathieson (1970). The authors investigated in detail, the composition, periodicity, and abundance of phytoplankton in relation to the trophic status of two New Hampshire lakes. One of the lakes, Newfound Lake, is oligotrophic, while Winnisquam Lake was considered to be in the early stages of eutrophication. A total of 185 species of phytoplankton was recorded. Gerhart and Likens (1975) compared 4 methods for determining nutrient limitation in enrichment experiments on Mirror Lake, a small oligotrophic lake. The flora was handled in a general manner and the phytoplankton assemblage consisted of many small flagellates. Kezar Lake, a small eutrophic lake, was artificially circulated during the warmer months to impede the annual bloom of bluegreen algae (Haynes 1975). Immediately after mixing was begun, *Aphanizomenon flos-aquae* bloomed.

Newfoundland

Cushman (1904) dealt with the desmids of the Rose au Rue area of Newfoundland. Some 20 taxa of desmids were reported, including critical notes. Cushman (1906b) published another paper on desmids that included some 72 species from St. Anthony's and Rose au Rue. In 1927 Hustedt described a new diatom species, *Surirella arguta*. Perhaps the most critical papers on Newfoundland algae were written by Taylor (1933, 1934). In these 2 papers, 581 algae are described with notes on the more difficult taxa. Taylor commented on the collection that, "pure myxophycean associations were very infrequent and that desmids alone characterized the flora of many of the samples." Taylor's notes include: Chlorophyceae, with some 428 forms of desmids; Myxophyceae; Euglenophyceae; Chrysophyceae, Dinophyceae; and Heterokontae. Taylor and Fogg (1927) sampled in late summer from the Bay of Islands area and reported 35 species of algae, exclusive of diatoms and desmids. Ruzicka (1949) produced a monograph on *Cosmarium hornavenense,* a quite variable species, including some forms from Newfoundland. Palmer and Black 1955) report 43 genera of algae from Argentia tap water samples claiming that the counts and algal composition indicate relatively clean water. A note by Palmer (1965) records that essentially the same succession of algal pulses occurred over a 4-yr. period, and the list of algae from Argentia had grown to 71 by the time of the report. Eight new genera from Newfoundland were included. A paper by Woodhead and Tweed (1961) from the Avalon Peninsula, reported that desmids, diatoms, and bluegreens were most abundant from their collections. Over 1000 taxa were identified, many of which were newly recorded for Canada. Davis (1972a, 1972b, 1973) studied several oligotrophic ponds on the Avalon Peninsula with relation to zoophytoplankton dynamics. Lakshminarayana (1976) found a total of 29 newly recorded algae from Newfoundland in a series of small ponds near St. John's, while O'Connell and Andrews (1977) did a seasonal and quantitative study of Long Pond. This pond receives both rural and urban runoff and has a high flushing rate. The phytoplankton were characterized by nannoplankton (particularly flagellates) and aspects of plankton ecology were discussed in relation to eutrophication.

Cedercreutz (1943) points out the similarities of the algae of Labrador and insular Newfoundland. In this paper, 229 taxa, excluding diatoms, are listed. Croasdale and Grönblad (1964) reported 24 genera and 362 species and varieties of desmids from the southeastern coastal area of Labrador. They suggest that the percentage of species of *Cosmarium* increases in the total flora with increasing latitudes. Duthie and Ostrofsky (1974) studied the plankton, chemistry, and physics of 10 lakes and reservoirs in the Churchill Falls region of western Labrador. They reported that diatoms were the most abundant group with flagellated Chrysophyta more abundant in the reservoir than in natural lakes. Specifically 28 algae were listed, but more were enumerated than those reported. The enumeration of these algae oc-

curred in Duthie and Ostrofsky (1975a, 1975b), Duthie, Ostrofsky, and Sreenivasa (1975) and Duthie, Ostrofsky, and Brown (1976). In these 4 papers the entire algal flora consisting of 545 taxa is compiled in an annotated list. Ostrofsky and Duthie (1975) used the ^{14}C method to determine the primary productivity of these bog lakes and performed enrichment experiments.

Nova Scotia

In Nova Scotia, Joshua (1885) published an annotated list of 11 desmids, 3 of which were from Pictou. A similar list of new and rare desmids was reported by Turner (1885) including 4 taxa from Nova Scotia. A summer collection by Roscoe (1931) included 2 species of freshwater *Batrachospermum* from St. Paul's Island, Victoria County. In 1938, Smith conducted a biological survey of Lake Jesse. Algae were identified by C.W. Lowe with 83 forms reported. One new genus and 5 new species were found by Hughes (1948) from a small lake near Medway River and a paper by Smith (1961) reported dystrophic conditions in Boar's Back Lake, a brown lake that had a bloom of *Peridinium limbatum*.

Prince Edward Island

Smith (1946) dealt with 5 ponds along the Prince Edward Island National Park, one pond was brackish and the others exposed to salt on occasion. The algae in Smith's (1946) study were identified by Hughes. Most of the 32 taxa were euryhaline, and most were identified to the generic level only. A study by Hughes (1950) spanned the 3 Maritime provinces with 537 taxa (excluding diatoms) reported. Of this total, 36 species from Prince Edward Island were recorded and most of these are characteristic of alkaline waters. Staker (1976) studied the algae of the Dunk River System in Prince County. His samples were taken either monthly (Sept.-April) or twice monthly during summer (May-Aug.) at 13 sampling stations. The total number of algal species recorded was 146. The algal flora of the Dunk River was described as a cyanophyte-chlorophyte type with chlorococcaceous greens dominating the large mill pond and filamentous greens dominating riffles and pools.

Québec

Some 31 studies to date have been conducted on Québec freshwater algae. The first was that of Kemp (1858), who describes a number of algae from the Montreal region. Miller (1915) recorded 54 species, mostly greens, from the Montreal island. Lowe (1927) recorded 305 taxa (40% of these being desmids) also from Montreal. Brunel (1932) studied the algal flora of Québec noting 73 species. Brunel added *Micrasterias expansa* to the Québec flora in (1940) and *Stephanodiscus binderanus* in (1956).

The desmids of the province of Québec are voluminously covered in the works of Irénée-Marie. In (1939), Irénée-Marie recorded some 527 species, varieties or forms of desmids from Montreal. The desmids of the Québec City region are discussed in several subsequent papers (1940, 1951a, 1951b, 1951c, 1952a) and for the Trois-Rivières region (1944, 1947, 1948a, 1949a, 1949b, 1954a, 1954b, 1956, 1957, 1958). Desmids of Lac Mistassini (1949c) were described including 262 taxa, and 553 forms of desmids were reported (1952b) for the region of Lac St. Jean. A new species from Grand Falls, New Brunswick, *Staurastrum hebeebense,* was described by Irénée-Marie in (1948b).

Prescott *et al.* (1949) described *Spirogyra pseudo-cylindrica* and *Bulbochaete glabra,* 2 new species from Gaspé Peninsula. Louis-Marie (1953) reported 71 taxa of algae, many of which were desmids, from the Laurentides. Two papers by Flint (1957a, 1957b) dealt primarily with swift-flowing streams forms including 4 species of red algae and 10 other lotic species. The phytoplankton composition and seasonality of Lac St. Francois were discussed by Cardinal (1964). Included were 153

Table 1. Orders represented in the survey with the number of taxa present in each province or state.

Division Order	ME	NB	NH	NFLD	NS	PEI	QUE
Bacillariophyta							
Centrales	1	8	9	5	1	1	21
Pennales	78	208	9	119	11	4	118
Chlorophyta							
Charales	1	0	1	0	0	0	0
Chlorococcales	40	90	50	47	58	10	106
Cladophorales	6	4	0	2	3	2	3
Oedogoniales	11	24	0	3	27	3	6
Schizogoniales	0	0	0	0	0	0	1
Tetrasporales	12	9	8	6	6	0	15
Ulotrichales	11	24	3	21	22	2	43
Ulvales	0	2	0	2	2	1	0
Volvocales	6	15	2	5	6	2	16
Zygnematales	458	497	448	1074	390	12	1457
Chrysophyta							
Chrysocapsales	0	0	0	0	0	0	1
Chrysomonadales	3	18	20	12	11	0	29
Rhizochrysidales	0	0	1	1	0	0	3
Cryptophyta							
Cryptomonadales	2	0	6	2	0	0	1
Cyanophyta							
Chaemaesiphonales	1	1	0	1	1	0	3
Chroococcales	10	50	10	47	31	3	42
Oscillatoriales	11	67	9	52	51	4	67
Euglenophyta							
Colaciales	0	0	2	0	0	0	0
Euglenales	19	3	1	2	3	0	23
Pyrrophyta							
Dinocapsales	0	2	0	0	2	0	0
Dinococcales	0	0	0	0	2	0	0
Gymnodiniales	0	0	2	0	0	0	1
Peridiniales	2	13	9	5	13	2	15
Rhodophyta							
Bangiales	1	0	1	0	0	0	1
Nemalionales	3	4	6	0	5	0	7
Xanthophyta							
Heterococcales	3	10	2	5	7	0	9
Heterosiphonales	4	9	0	3	6	1	8
Heterotrichales	0	1	0	6	1	1	4
Rhizochloridales	0	1	1	0	1	0	1
TOTALS	683	1060	600	1421	660	48	2001

phytoplankters, while 458 taxa were enumerated by Bourrelly (1966) for the region of the Mont Tremblant Park.

In addition to the above, there are a number of papers that concern several provinces, or several states, or a combination. Borge (1909) lists 39 algae from Québec and Nova Scotia. A total of 107 desmid taxa area reported by Brown (1930) from Maine, New Hampshire, Newfoundland, and Québec, among the other algae, most of which were from the southeastern coastal plain region of the United States. Cushman (1906a, 1907a, 1907b, 1908a, 1908b) studied extensively the desmids of New England and these papers included work on the sub-family Saccodermae, and the genera *Pleurotaenium, Tetmemorus, Closterium,* and *Micrasterias* respectively. Collins (1909, 1912, 1918) compiled a book and two addenda to his algae of North America. The book was a comprehensive study of all known Chlorophyceae from the Arctic Ocean to the Isthmus of Panama. Both marine and freshwater forms were described with a special emphasis on New England forms. In (1942), Gustafson published on some of the freshwater algae from New England. Included were some notes on the distribution and occurrence of 35 species, predominantly from Maine and New Hampshire. Palmer (1958) speaks of the algae and other interference organisms in New England water supplies. He also discusses the relationships between New England and Newfoundland algal floras.

Discussion and Conclusions

Earlier papers from this region are often descriptive in their approach with the emphasis on algal taxonomy. Obvious examples are the works of Baxter, Collins, Cushman, Harvey, Irénée-Marie, Taylor, and West. Many of the more recent papers are ecological or even experimental in nature with the stress away from systematics. Noteworthy are the works of Besch *et al.* Gerhart and Likens, Haynes, Mackenthum *et al.* O'Connell and Andrews, and Ostrofsky and Duthie. This may be a reflection of the research trends of today with much of the effort focused on environmental studies. There are no algal systematists, like Croasdale, Irénée-Marie, or Taylor, actively working in this area now.

Floristically speaking, the desmids are the qualitative prominent form throughout this region (*cf* Table I[a]. This is especially true of Quebec and Newfoundland where sphagnum bogs are commonplace. The literature review does not show Prince Edward Island to follow this trend, but this is probably due to the fact that the Dunk River, an alkaline stream, was the only body of water studied extensively.

Bibliography

Baxter, J.M. 1903. Microscopic forms in freshwater. Miramichi *Nat. Hist. Assoc. Proc.* 3: 5-10.

Baxter, J.M. 1905. Fresh water life. *Miramichi Nat. Hist. Assoc. Proc.* 4: 12-18.

Baxter, J.M. 1907. Microscopic forms in fresh water. *Miramichi Nat. Hist. Assoc. Proc.* 5: 18-20.

Besch, W.K., Ricard, M., and **Cantin R.** 1972. Benthic diatoms as indicators of mining pollution in the Northwest Miramichi River System, New Brunswick, Canada. *Int. Rev. Gesamten Hydrobiol.* 57: 39-72.

Blum, J.L. 1943. New species of Spirogyra. *Am. J. Bot.* 30: 783.

Borge, O. 1909. Nordamerikanische Suesswasseralgen. *Ark. Bot.* 8: 1-30.

Bourrelly, P. 1966. Quelques algues d'eau douce du Canada. *Int. Rev. Gesamten Hydrobiol.* 55: 45-126.

Brown, H.J. 1930. The desmids of the southeastern coastal plain region of United States. *Trans. Am. Microsc. Soc.* 49: 97-131.

Brunel, J. 1932. Etudes sur la flore algologique due Québec. I *Contrib. Lab. Bot. Univ. Montreal.* 22: 3-19.

Brunel, J. 1940. Addition du *Micrasterias expansa* à la flore du Québec. *Acfas* 6:104.

Brunel, J. 1956. Addition du *Stephanodiscus binderanus* à la flore diatomique de L'Amerique du Nord. *Nat. Can.* 83: 89-95.

Cardinal, A. 1964. The phytoplankton of Lake St.-Francois (Canada). *Nova Hedwigia.* 7: 11-14.

Cedercreutz, C. 1943. Fresh water algae from Labrador. *Soc. Fauna Flora Fenn. Mem.* 19: 216-222.

Cole, R.M. 1939. Studies on the plankton of the Connecticut watershed. *New Hampshire Fish. Game Dep. Biol. Surv. Rep.* 3: 190-194.

Collins, F.S. 1909. The green algae of North America. *Tufts Coll. Stud. Sci. Ser.* 2:79-480.

Collins, F.S. 1912. The green algae of North America. *Suppl. Paper, Tufts Coll. Stud. Sci.* Ser. 3:69-109.

Collins, F.S. 1918. The green algae of North America. *Second Suppl. Tufts Coll. Stud. Sci. Ser.* 4: 1-106.

Cooper, G.P. 1939. A biological survey of thirty-one lakes and ponds of the upper Saco River and Sebago Lake drainage systems in Maine. *Maine. Dep. Inland Fish. Game, Fish Surv. Rep.* 2:1-147.

Cooper, G.P. 1940. A biological survey of the Rangeley Lakes, with special reference to the trout and salmon. *Maine Dep. Inland Fish. Game, Fish Surv. Rep.* 3: 1-182.

Cooper, G.P. 1942a. A biological survey of lakes and ponds of the Androscoggin and Kennebec River drainage systems in Maine. *Maine Dep. Inland Fish. Game, Fish. Surv. Rep.* 4: 1-238.

Cooper, G.P. 1942b. A biological survey of lakes and ponds of the central coastal area of Maine. *Maine Dep. Inland Fish. Game, Fish. Surv. Rep.* 5: 1-184.

Cooper, G.P. and **Fuller, J.L.** 1945. A biological survey of Moosehead Lake and Haymock Lake, Maine. *Maine Dep. Inland Fish. Game, Fish. Surv. Rep.* 6: 1-160.

Croasdale, H. and **Grönblad, R.** 1964. Desmids of Labrador I. Desmids of the southeastern coastal area. *Trans. Am. Microsc. Soc.* 83: 142-212.

Cushman, J.A. 1904. Desmids from Newfoundland. *Bull. Torrey Bot. Club.* 31: 581-584.

Cushman, J.A. 1905. A contribution to the desmid flora of New Hampshire. *Rhodora.* 7: 111-119.

Cushman, J.A. 1906a. New England desmids of the sub-family Saccodermae. *Bull. Torrey Bot. Club.* 33: 343-351.

Cushman, J.A. 1906b. Some desmids from Newfoundland. *Bull. Torrey Bot. Club.* 33: 607-615.

Cushman, J.A. 1907a. A synopsis of the New England species of *Pleurotaenium. Rhodora.* 9: 101-106.

Cushman, J.A. 1907b. A synopsis of the New England species of *Tetmemorus. Bull. Torrey Bot. Club.* 34: 599-601.

Cushman, J.A. 1908a. The New England species of *Closterium. Bull. Torrey Bot. Club.* 35: 109-133.

Cushman, J.A. 1908b. A synopsis of the New England species of *Micrasterias. Rhodora.* 10: 97-111.

Davis, C.C. 1972a. Plankton dynamics in a Newfoundland lake. *Verh. Int. Verein. Limnol.* 18: 278-283.

Davis, C.C. 1972b. Plankton succession in a Newfoundland lake. *Int. Rev. Gesamten Hydrobiol.* 57: 367-395.

Davis, C.C. 1973. A seasonal quantitative study of the plankton of Bauline Long Pond, a Newfoundland lake. *Nat. Can.* 100: 85-105.

Duthie, H.C. and **Ostrofsky, M.L.** 1974. Plankton, chemistry and physics of lakes in the Churchill Falls region of Labrador. *J. Fish. Res. Board Can.* 31: 1105-1117.

Duthie, H.C. and **Ostrofsky, M.L.** 1975a. Freshwater algae from Western Labrador II. Chlorophyta and Euglenophyta. *Nova Hedwigia.* 26: 253-268.

Duthie, H.C. and **Ostrofsky, M.L.** 1975b. Freshwater algae from Western Labrador III. Cyanophyta and Rhodophyta. *Nova Hedwigia*. 26: 555-560.

Duthie, H.C. and **Brown, D.J.** 1976. Freshwater algae from Western Labrador IV. Chyrsophyta, Xanthophyta, Cryptophyta. *Nova Hedwigia*. 27: 909-917.

Duthie, H.C. and **Sreenivasa, M.R.** 1975. Freshwater algae from Western Labrador I. Introduction and Bacillariphyta. *Nova Hedwigia*. 26: 17-32.

Flint, L.H. 1948. Studies on fresh water red algae. *Am. J. Bot.* 35: 428-433.

Flint, L.H. 1953. *Kyliniella* in America. *Phytomorphology*. 3: 76-80.

Flint, L.H. 1957a. Notes on algae of Québec. I. Mont Tremblant Provincial Park. *Nat. Can.* 84: 157-160.

Flint, L.H. 1957b. Notes on algae of Québec. II. Laurentide Park. *Nat. Can.* 84: 179-181.

Gerhart, D.L. and **Likens, G.E.** 1975. Enrichment experiments for determining nutrient limitation: four methods compared. *Limnol. Oceanogr.* 20: 649-653.

Gruendling, G.K. and **Mathieson, A.C.** 1970. Phytoplankton flora of Newfound and Winnisquam Lakes, New Hampshire. *Rhodora*. 71: 444-477.

Gustafson, A.H. 1942. Notes on some fresh-water algae from New England. *Rhodora*. 44: 64-69.

Habeeb, H. and **Drouet, F.** 1948. A list of fresh-water algae from New Brunswick. *Rhodora*. 50: 67-71.

Harvey, F.L. 1888. The fresh-water algae of Maine. I. *Bull. Torrey Bot. Club*. 15: 155-161.

Harvey, F.L. 1889. The fresh-water algae of Maine, II. *Bull. Torrey Bot. Club*. 16: 181-183.

Harvey, F.L. 1892. The fresh-water algae of Maine. III. *Bull. Torrey Bot. Club*. 19: 118-125.

Hastings, W.N. 1892. New desmids from New Hampshire. I. *Am. Microsc. J.* 13: 153-155.

Haynes, R.C. 1975. Some ecological effects of artificial circulation on a small eutrophic lake with particular emphasis on phytoplankton. II. Kezar Lake, experiment, 1969. *Hydrobiologia*. 46: 141-170.

Hoover, E.E. 1937. Biological survey of the Androscoggin, Saco and coastal watersheds. *New Hampshire Fish and Game Dep. Surv. Rep.* 2: 1-160.

Hoover, E.E. 1938. Biological survey of the Merrimack watershed. *New Hampshire Fish and Game Dept. Surv. Rep.* 3: 1-238.

Hughes, E.O. 1948. New fresh-water Chlorophyceae from Nova Scotia. *Am J. Bot.* 35: 424-427.

Hughes, E.O. 1950. Fresh-water algae of the maritime provinces. *Proc. N.S. Inst. Sci.* 22: 1-63.

Hughes, E.O. 1952. Phytoplankton of some maritime lakes. *Can. Field Nat.* 66: 167-170.

Hustedt, F. 1927. Vorläufige Erlauterungen zu Dr. A. Schmidts' Atlas der Diatomaceenkunde In: *Atlas der Diatomaceenkunde*. 92: 365-368.

Iréneé-Marie, F. 1939. *Flore Desmidiale de la Region de Montréal*. Lapraire, Canada.

Iréneé-Marie, F. 1940. Contribution à la connaissance desmidiées du Québec. *Nat. Can.* 67: 97-112.

Iréneé-Marie, F. 1944. Contribution à la connaissance des desmidiées de la region des Trois-Rivières. *Nat. Can.* 74: 273-287.

Iréneé-Marie, F. 1947. Contribution à la connaissance des desmidiées de la region des Trois-Rivières. *Nat. Can. 74: 102-124.*

Iréneé-Marie, F. 1948a. Contribution à la connaissance des desmidiées de la region des Trois-Rivières. *Nat. Can.* 75: 139-173.

Iréneé-Marie, F. 1948b. Un nouveau *Staurastrum canadien, Acfas* 14: 94-95.

Iréneé-Marie, F. 1949a. Contribution à la connaissance des desmidiées de la region des Trois-Rivières. *Nat. Can. 76: 16-42.*

Iréneé-Marie, F. 1949b. Contribution à la connaissance des desmidiées de la region des Trois-Rivières. *Nat. Can.* 76:99-134.
Iréneé-Marie, F. 1949c. Quelques desmidiées du Lac Mistassini. *Nat. Can.* 76: 242-262, 265-347.
Iréneé-Marie, F. 1951a. Desmidiées de la région de Québec. *Nat. Can.* 78: 88-127.
Iréneé-Marie, F. 1951b. Desmidiées de la région de Québec. *Nat. Can.* 78: 177-221.
Iréneé-Marie, F. 1951c. Desmidiées de la région de Québec. *Nat. Can. 78: 301-339.*
Iréneé-Marie, F. 1952a. Desmidiées de la région de Québec. *Nat. Can.* 79: 11-45.
Iréneé-Marie, F. 1952b. Contribution à la connaissance des desmidiées de la région du Lac-St.-Jean. *Hydrobiologia.* 4: 1-208.
Iréneé-Marie, F. 1954a. Flore desmidiale de la région des Trois-Rivières. *Nat. Can.* 81: 5-49.
Iréneé-Marie, F. 1954b. Flore desmidiale de la région des Trois-Rivières. *Nat. Can.* 81: 69-90.
Iréneé-Marie, F. 1956. Les *Cosmarium* de la région des Trois-Rivières. *Hydrobiologia.* 8: 79-154.
Iréneé-Marie, F. 1957. Les *Staurastrum* de la région des Trois-Rivières. *Hydrobiologia.* 9: 145-209.
Iréneé-Marie, F. 1958. Contribution à la connaissance des desmidiées de la région des Trois-Rivières. *Nat. Can.* 85: 1, 5-134.
Joshua, W. 1885. On some new and rare Desmidiae. III. *J. Bot.* 23: 33-35.
Kemp, A.F. 1858. The fresh water algae of Canada. *Can. Nat. Geol.* 3: 331-345.
Klugh, A.B. 1921. A new genus and three new species of algae from the Miramichi River, New Brunswick. *Contrib. Can. Biol. Fish.* 1918-1920: 181-183.
Klugh, A.B. 1927. The ecology, food-relations and culture of fresh-water entomostraca. *Trans. R. Can. Inst.* 16: 15-98.
Lakshminarayana, J.S.S. 1976. Studies on a series of small fresh-water pools near St. John's Newfoundland: II algae. *Hydrobiologia.* 49: 129-135.
Louis-Marie, P. 1953. Quelques algues des Laurentides. *Rev. Oka.* 27: 22-24.
Lowe, C.W. 1927. Some freshwater algae of southern Québec *Trans. R. Soc. Can.* 21: 291-318.
Mackenthum, K.M., Keup, L.E., and **Steward, R.K.** 1968. Nutrients and algae in Lake Sebasticook, Maine. *J. Water Pollut. Control Fed.* 40: R72-R81.
Miller, C.R. 1915. Fresh-water algae occurring in the vicinity of the island of Montreal. *Can. Rec. Sci.* 9: 391-425.
O'Connell, M.F. and **Andrews, C.W.** 1977. Plankton ecology in Long Pond, St. John's, Newfoundland: A polluted pond characterized by a high flushing rate. *Int. Rev. Gesamten Hydrobiol.* 62: 133-152.
Ostrofsky, M.L. and **Duthie, H.C.** 1975. Primary productivity, phytoplankton and limiting nutrient factors in Labrador lakes. *Int. Rev. Gesamten Hydrobiol.* 60: 145-158.
Palmer, C.M. 1958. Algae and other interference organisms in New England water supplies. *J.N. Engl. Water Works Assoc.* 72: 27-46.
Palmer, C.M. 1965. Phytoplankton periodicity in a Newfoundland pond. *J. Phycol.* 1: 39-40.
Palmer, C.M. and **Black, H.H.** 1955. Report on plankton removal tests and potable water survey at Naval Station, Argentia, Newfoundland. August 19 to August 31, 1954. *Rep. Dep. Navy Bureau Yards Docks.* (Wash.)
Prescott, G.W., Silva, H., and **Wade, W.E.** 1949. New or otherwise interesting fresh-water algae from North America. *Hydrobiologia* 2: 84-93.
Roscoe, M.V. 1931. The algae of St. Paul Island. *Rhodora* 33: 127-131.
Ruzicka, J. 1949. *Cosmarium hornavenense* Gutw. *Sb. Nar. Mus. Praze* B: 1-69.
Smith, M.W. 1938. A survey of Lake Jesse, Nova Scotia. *Proc. N.S. Inst. Sci.* 19: 253-263.

Smith M.W. 1946. A biological reconnaissance of ponds in the Prince Esward Island National Park. *Acadian Nat.* 2: 81-101.

Smith, M.W. 1952. Limnology and trout angling in Charlotte County Lakes, New Brunswick. *J. Fish. Res. Board Can.* 8: 383-452.

Smith, M.W. 1961. A limnological reconnaissance of Nova Scotian brown-water lake. *J. Fish. Res. Board Can.* 18: 463-478.

Staker, R.D. 1976. Algal composition and seasonal distribution in the Dunk River System, Prince Edward Island *Nova Hedwigia* 27: 731-745.

Taylor, W.R. 1921. Additions to the flora of Mount Desert, Maine. *Rhodora* 23: 65-68.

Taylor, W.R. 1933. The fresh-water algae of Newfoundland. I. *Mich. Acad. Sci. Arts Letters* 19; 217-278.

Taylor, W.R. 1934. The fresh-water algae of Newfoundland. II. *Mich. Acad. Sci. Arts Letters* 20: 185-230.

Taylor, W.R. and **Fogg, J.M.** 1927. Notes on some freshwater algae from Newfoundland. *Rhodora* 29: 160-164.

Transeau, E.N., Tiffany, L.H., Taft, C.E., and **Li, L.C.** 1934. New species of Zygnemataceae. *Trans. Am. Microsc. Soc.* 53: 208-230.

Turner, W.B. 1885. On some new and rare desmids. *J.R. Microsc. Soc.* 5: 933-940.

Unger, W.B. 1941. A preliminary survey of the Protozoa of Beaver Lake near Salsbury Cove, Maine. *Mount Desert Island Biol. Lab. Bull.* 17-18.

West, W. 1888. The desmids of Maine. *J. Bot.* 26: 339-340.

West, W. 1889. The freshwater algae of Maine. *J. Bot.* 27: 205-207.

West, W. 1891. The freshwater algae of Maine. *J. Bot.* 29: 353-357.

Wheldon, R.M. 1942. Notes on New England algae. *Rhodora* 44: 175-187.

Wheldon, R.M. 1943. Notes on New England algae. Farlowia 1: 9-23.

Wood, H.C. 1869. Desmids from the White Mountains. *Proc. Acad. Nat. Sci.* (Phil.) 15-19.

Woodhead, N. and **Tweed, R.D.** 1961. Additions to the algal flora of Newfoundland. Part 1: New and interesting algae in the Avalon Peninsula and central Newfoundland. *Hydrobiologia* 15: 309-362.

Addendum

A checklist of the freshwater algae of Ontario, exclusive of the Great Lakes, was recently presented by Duthie and Socha (1976) which includes some 2073 taxa.

Duthie, H.C. and **Socha, R.** 1976. A checklist of the freshwater algae of Ontario, exclusive of the Great Lakes. *Nat. Can.* 103: 83-110.

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INVESTIGATIONS OF THE MARINE ALGAE OF NOVA SCOTIA XIV. *COLPOMENIA PEREGRINA* SAUV. (PHAEOPHYTA: SCYTHOSIPHONACEAE)[1]

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The occurrence of *Colpomenia peregrina* in Nova Scotia is established from 5 collections of the species from 1960 to 1977. Plants were found between May and August in the upper sublittoral zone, to 3 to 5 m below mean low water, at sites on the Atlantic coast of the province and the Bay of Fundy approaches. Thalli ranged to 25 cm in diameter, and plurilocular sporangia occurred sparingly on the largest plants, collected in June. The records from Halifax County, N.S. represent the present northern limits of distribution of *C. peregrina* in eastern North America.

Introduction

Colpomenia peregrina Sauv. is a cosmopolitan alga of widespread if discontinuous occurrence in the northern Atlantic Ocean (Blackler 1967), including occasional records from eastern Canada (Blackler 1964; MacFarlane & Milligan 1966). However, the species was excluded from the current eastern Canadian check-list of marine algae (South 1976) pending substantiation of the latter records. On the basis of a study of available herbarium specimens, we now confirm the presence of *C. peregrina* in Nova Scotia.

Materials and Methods

Collections of *Colpomenia peregrina* from Nova Scotia (Table 1) were located in the herbaria of the Atlantic Regional Laboratory (NRCC), the Nova Scotia Museum (NSPM), and the University of New Brunswick (UNB). Collection sites are indicated in Figure 1.

Portions of dried thalli were rehydrated in a 3% aqueous solution of potassium hydroxide, and sectioned with a freezing microtome. Formalin-preserved material proved more satisfactory for sectioning than pressed specimens, which were fragile and often persistently semi-collapsed after rehydration. Thus, illustrations and measurements of microscopic features were taken only from liquid-preserved plants.

[1]*NRCC NO. 16775*
**Deceased*

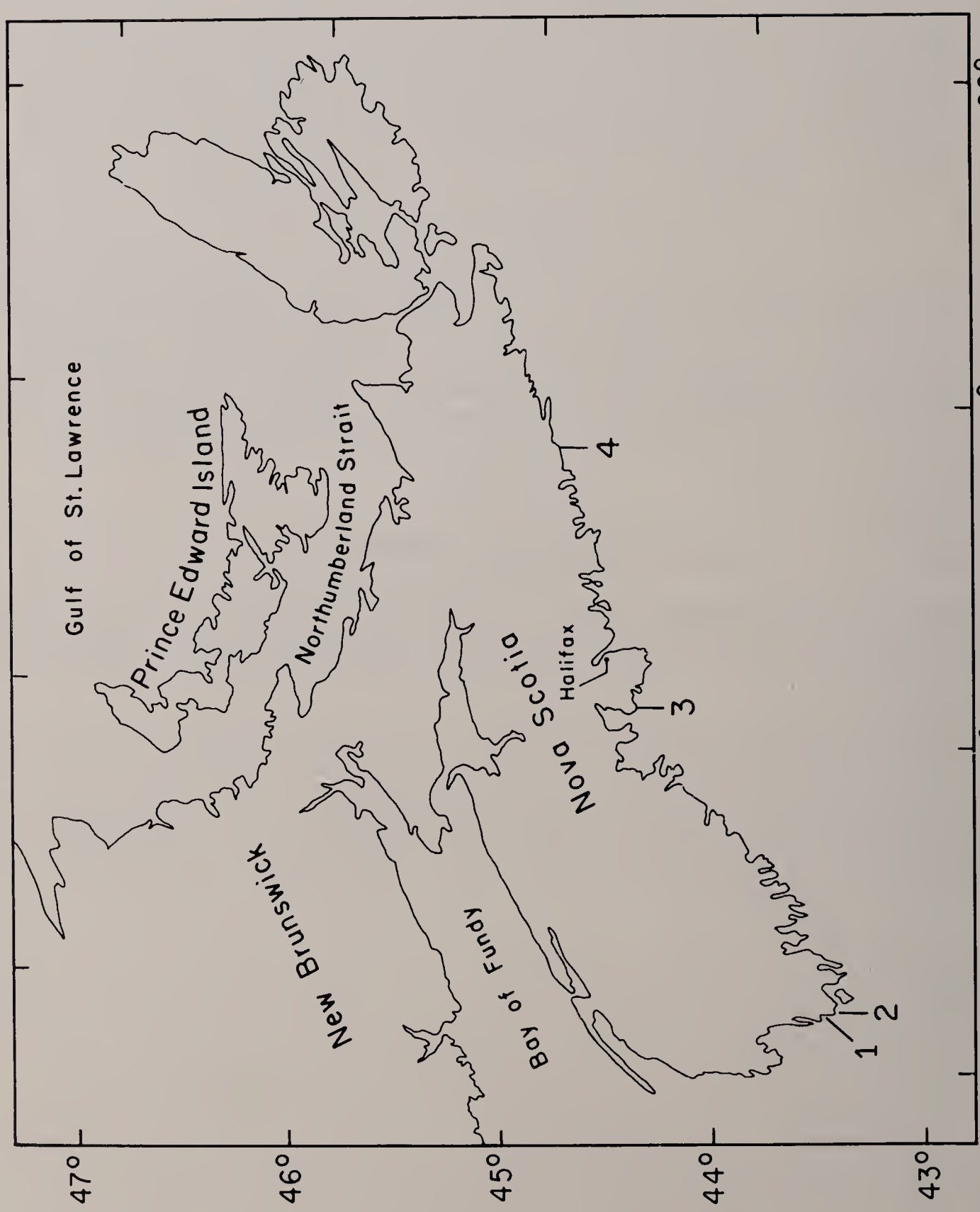


Fig 1.

Collection sites of *Colpomenia peregrina* in Nova Scotia.
1. Goodwin Island;
2. Bon Portage Island;
3. Polly Cove;
4. Atkins Point.

Table 1 Synopsis of Nova Scotian collections of *Colpomenia peregrina*

Locality	Date	Depth	Substratum (Host)	Collector(s)	Herbarium reference
Atkins Point Halifax Co.	15 July 1960	upper sublittoral		A.R.A. Taylor	UNB NS-16*
Goodwin I., Shelburne Co.	29 June 1966	3-4 m	*Chondrus Cladosiphon Zostera*	G.M. Milligan G.A. Neish	NSPM 1966-57†
Polly Cove Halifax Co.	24 May 1967	3-5 m	*Chondrus Rhodomela*	D. Pace	NRCC-6400
Polly Cove Halifax Co.	5 June 1967	3-5 m	*Chondrus Rhodomela*	D. Pace	NRCC-6401
Bon Portage I. Shelburne Co.	4 Aug. 1977	3 m	*Phyllophora*	M. Greenwell J.S. Wilson	NRCC-7148

*Temporary designation

†Number from the herbarium of the Nova Scotia Research Foundation Corporation

Description of Nova Scotian *Colpomenia peregrina*

As the distrinction of species of *Colpomenia* is sometimes equivocal (Clayton 1975; Wynne 1972), it is worthwhile to include a description of Nova Scotian material, as determined from the NRCC collections.

Young thalli subglobose, thin-walled vesicles (Fig 2), smooth except for scattered cryptostomata; older thalli becoming irregularly bullate, coarser, up to 21 cm in overall diameter; plants generally epiphytic, sessile, attached by a compact tangle of rhizoids; color of fresh specimens light olive to olive-brown, of pressed thalli olive-brown to yellow-brown.

Cortical cells polygonal in surface aspect (Fig 5), 9 to 21 μm in their longest dimension, in section flattened and forming a monostromatic or rarely distromatic pigmented layer 9 to 13 μm thick (Fig 3), near the base of the thallus often produced into aseptate or sparingly septate rhizoids (Fig 4) of irregular diameter and with occasional branching. Medulla of 2 to 4 layers of ovoid, nearly colorless vesicular cells, larger than the cortical cells and increasing markedly in diameter towards the lumen of the thallus (when 4 medullary cell layers present, the outermost cells usually transitional in size and pigmentation to the cortical cells). Cryptostomatal hairs originating from the medullary cells, meristematic immediately above the point of origin (Fig 3).

Plurilocular sporangia in small, diffuse patches on the lower portion of the thallus, not in discrete sori or strictly associated with cryptostomata (Fig 5), consisting of 1 to 4 files of locules 5.5 to 9.0 μm broad, 15 to 24 μm deep, lacking a cuticle. Paraphyses ovoid, sessile on cortical cells, darkly pigmented [in formalin-preserved material; *cf.* Lund (1945)], 17 to 42 μm broad (Figs 5,6), persistent after

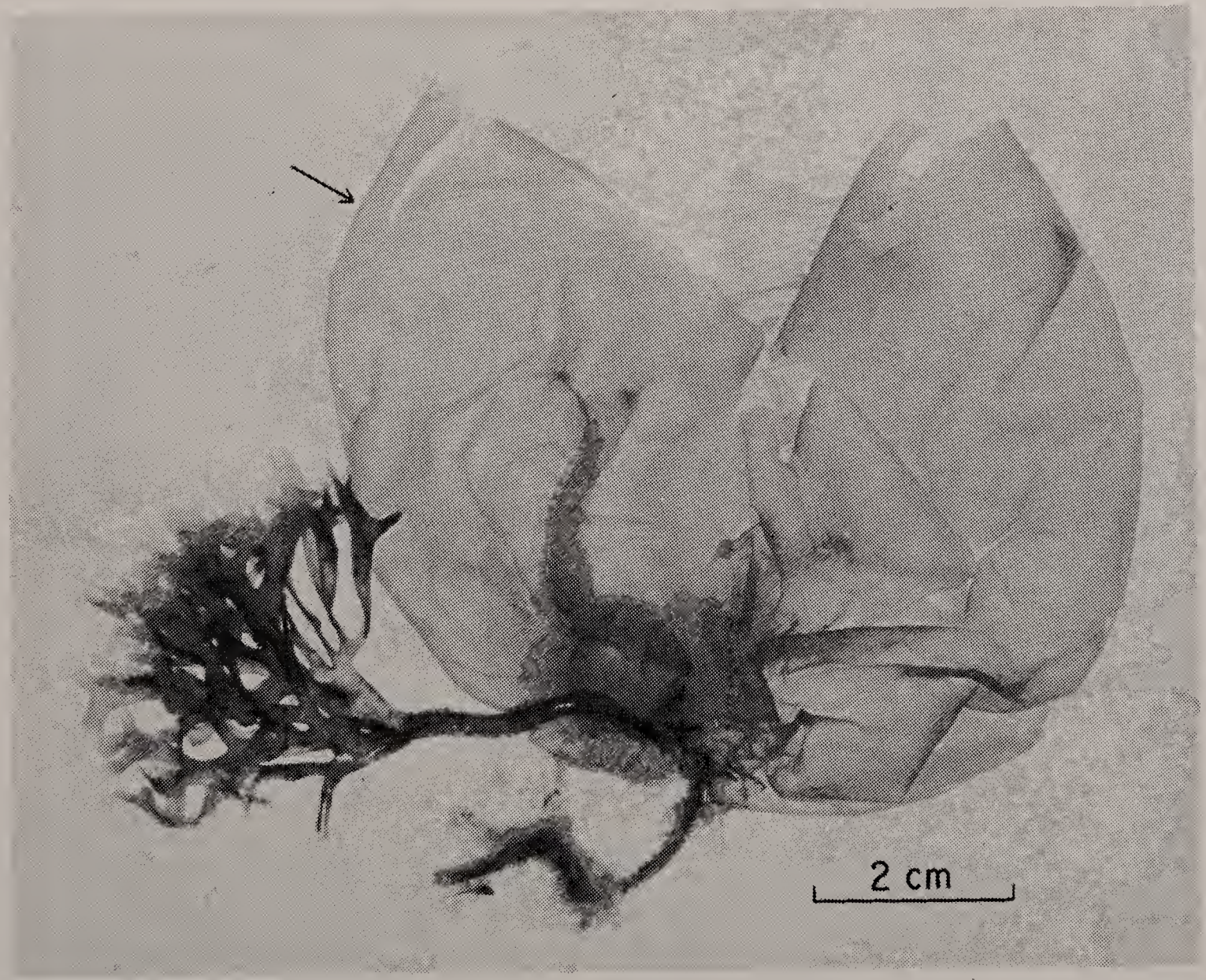
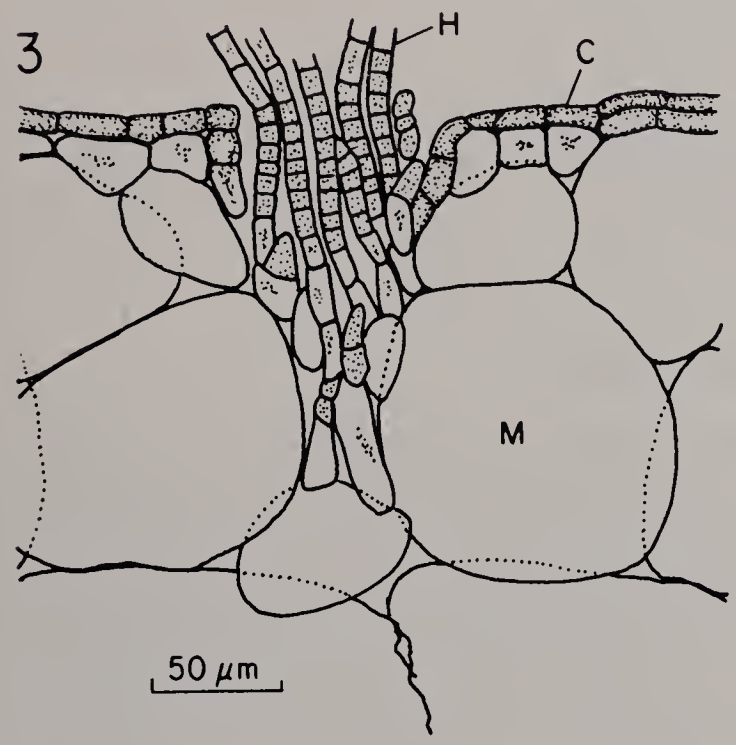
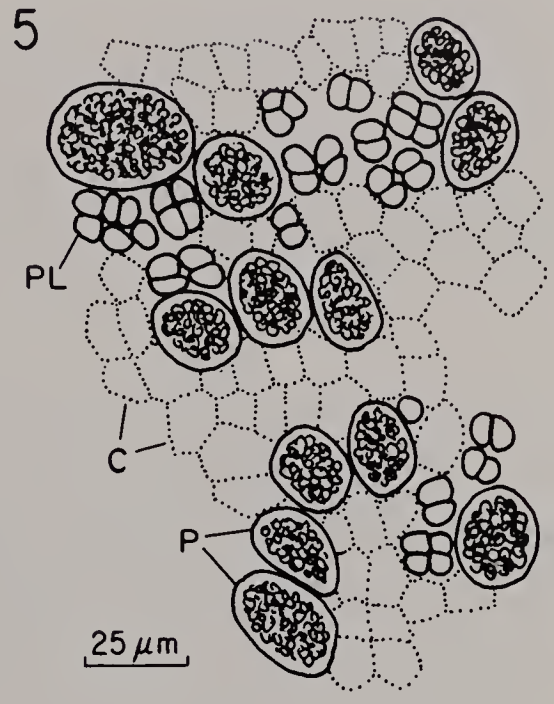
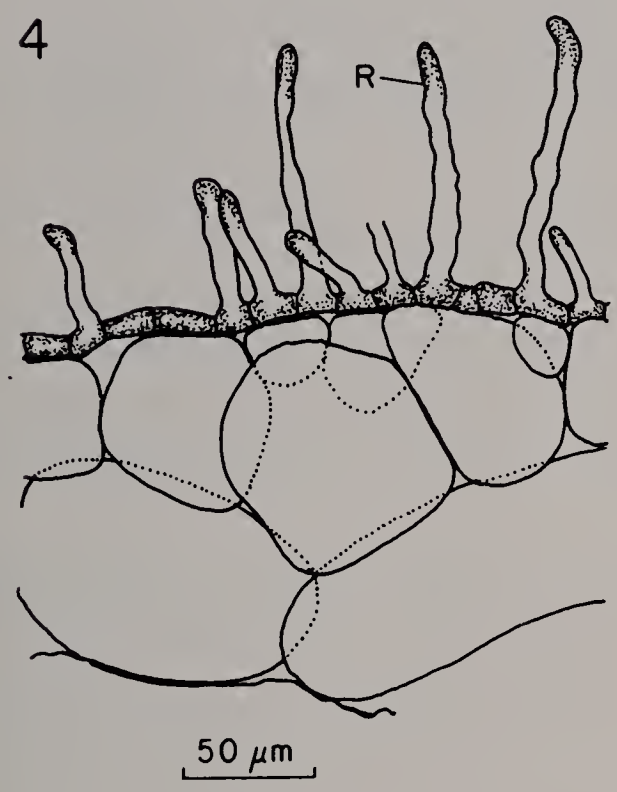


Fig 2. *Colpomenia peregrina*. A young plant (arrow) on *Chondrus crispus Stackh.*, NRCC 6400.

Figs 3-6. Microscopic anatomy of *Colpomenia peregrina*. C—cortical cell; E—empty plurilocular sporangium H—hair, M—medulla, P—paraphysis, PL—plurilocular sporangium, R—rhizoid.







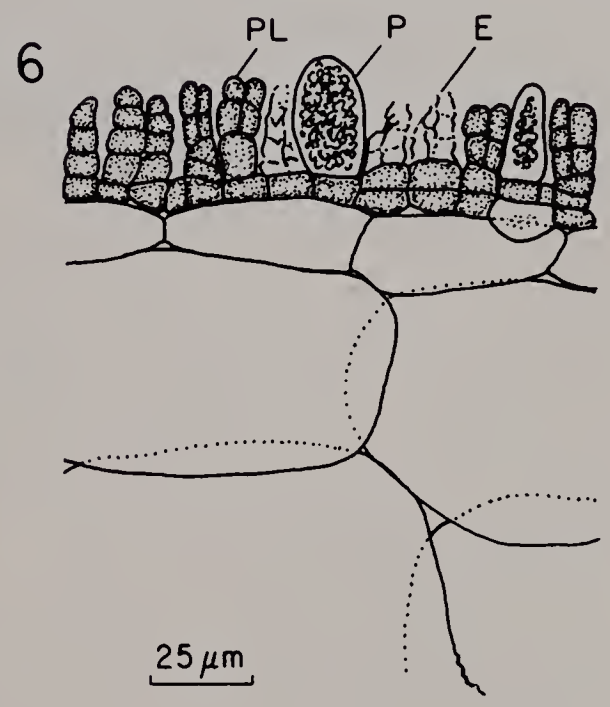


Fig 3. Anticlinal section of an older thallus, showing pigmented cortex over large-celled medulla, and a cryptostoma with hairs issuing from the medullary cells; NRCC 6400.

Fig 4. Anticlinal section from basal region of thallus, with rhizoids developing from cortical cells; NRCC 6400.

Fig 5. Surface view of a fertile portion of a thallus, with plurilocular sporangia and paraphyses; cortical cells are outlined with dotted lines to indicate their lower focal plane; NRCC 6401.

Fig 6. Same as Fig 5, in anticlinal section, showing empty sporangia.

discharge of plurilocular sporangia (Fig 6). Only the largest plants (Polly Cove, June collection) were fertile, and then only sparingly so. Sori were identifiable under low (25-50X) magnification by the presence of the darker paraphyses.

The Goodwin Island (NSPM) collection was essentially identical with the NRCC specimens. A note on the label of 1966-57 states that fresh specimens ranged to 25 cm in diameter. Again, only the largest plants were fertile, but in contrast with the Polly Cove material, paraphyses were not observed.

The Atkins Point (UNB) specimen, a juvenile plant 2.8 cm in diameter as pressed, was identified as *C. peregrina* by H. Blackler and erroneously ascribed by her to New Brunswick (Blackler 1964). Anatomically, it was identical with young plants in the NRCC collections.

Discussion

Clayton (1975) compared Australian populations of *Colpomenia peregrina* and *C. sinuosa* (Roth) Derbès et Solier, and concluded that the only valid distinctions between the 2 species were diffuse disposition of plurilocular sporangia and absence of a soral cuticle in *C peregrina*. On the basis of these criteria, the present specimens are assigned to *C. peregrina*. They also possess other features previously considered indicative of *C. peregrina* (Lund 1945)—medullary origin of cryptostomatal hairs and fewer layers of medullary cells—although the coarse, bullate convolutions of older thalli are traditionally more suggestive of *C. sinuosa*. However, *C. sinuosa* is a more southerly species which, on this coast, has not been reported north of North Carolina, while *C. peregrina* is widely known from colder waters (Blackler 1967). Wynne's (1972) contention that *C. peregrina* is a synonym of *C. bullosa* (Saund.) Yamada remains to be investigated pending an opportunity to study the latter species.

The significance of the absence of paraphyses in fertile Goodwin Island specimens is not clear. Earlier reports claim paraphyses in *C. peregrina* to be variable in number (Lund 1945; Rosenvinge & Lund 1974), but generally more common than in *C. sinuosa* (Blackler 1964). Clayton (1975) did not consider paraphyses in her analysis of morphological and anatomical differences between these two species, and evidently attached little importance to them. However, presence or absence of paraphyses has been used as a critical taxonomic feature in the related genus *Scytosiphon* (Wynne 1969).

As the present records indicate, *C. peregrina* is a rare species in Nova Scotian waters, although multiple plants occurred in some instances. Recurrent populations have not been noted; numerous subsequent collections at Polly Cove, until the sublittoral algal flora was removed by sea urchins, failed to turn up additional specimens. Nor was the species observed again at Atkins Point in September and October of 1970 and 1971 (A.R.A. Taylor, *in litt.*), although its absence in this case could be due to the later collection dates. Further search at Bon Portage and Goodwin Islands is still pending, and it is hoped that the persistent rich algal flora in this area will foster additional occurrences. The sporadic records thus far suggest that *C. peregrina* is adventive in these waters, the present northern limits of its distribution in eastern North American.

Bon Portage Island was revisited on August 23, 1978, and numerous thalli of *C. peregrina* were observed in the same site as the original collection of August 1977 (NRCC 7148).

Acknowledgements

Dr. D. Pace kindly donated his collections of *C. peregrina* to the Atlantic Regional Laboratory. The senior author thanks Dr. A.R.A. Taylor of the University of New

Brunswick for the loan of his herbarium specimen of *Colpomenia* and for his helpful remarks concerning it.

References

Blackler, H. 1964. Some observations on the genus *Colpomenia* (Endlicher) Derbès et Solier 1851. *Proc. Int. Seaweed Symp.* 4: 50-54.

Blackler, H. 1967. The occurrence of *Colpomenia peregrina* (Sauv.) Hamel in the Mediterranean (Phaeophyta, Scytosiphonales). *Blumea* 15: 5-8

Clayton, M.N. 1975. A study of variation in Australian species of *Colpomenia* (Phaeophyta, Scytosiphonales). *Phycologia* 14: 187-195.

Lund, S. 1945. On *Colpomenia peregrina* Sauv. and its occurrence in Danish waters. *Rept. Dan. Biol. Stn.* 47: 1-16.

MacFarlane, C.I. and **Milligan, G.M.** 1966. *Marine Algae of the Maritime Provinces of Canada. A Preliminary Check List.* N.S. Res. Fond., Seaweeds Div., Dartmouth. 32 p. (mimeogr.)

Rosenvinge, L.K. and **Lund, S.** 1947. The marine algae of Denmark. Contributions of their natural history. II. Phaeophyceae, 3. *K. Danske Vidensk. Selsk. Biol. Skrift.* IV. Copenhagen.

South, G.R. 1976. A check-list of marine algae of eastern Canada—first revision. *J. Mar. Biol. Ass. U.K.* 56: 817-843.

Wynne, M.J. 1969. Life history and systematic studies of some Pacific North American Phaeophyceae (brown algae). *Univ. Calif. Publ. Bot.* 50: 1-88.

Wynne, M.J. 1972. Studies on the life forms in nature and in culture of selected brown algae. In: *Contributions to the Systematics of Benthic Marine Algae of the North Pacific,* pp. 133-145. (Eds. Abbott, I.A. and M. Kurogi). Japanese Society of Phycology, Kobe.

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INVESTIGATIONS OF THE MARINE ALGAE OF NOVA SCOTIA XV. *LOMENTARIA ORCADENSIS* (RHODOPHYTA, CHAMPIACEAE)[1]

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The marine red alga *Lomentaria orcadensis* is reported for the first time from Canada. Plants were collected in August approximately 8 m below mean sea level, and were tetrasporic.

Species of the marine red algal genus *Lomentaria* Lyngbye are plants of the temperate North Atlantic and Pacific Oceans (Kylin 1956). In eastern Canada, the only prior record of this genus is the warm-water species *L. baileyana* (Harv.) Farl., which occurs in estuaries and embayments of the Gulf of St. Lawrence (Edelstein et al. 1967; in herb. Atl. Reg. Lab., NRCC), a disjunct northern extension of its range in the western Atlantic. The more northerly affiliated *L. orcadensis* (Harv.) Coll. ex Taylor, although reported to occur in eastern North America from North Carolina to Maine (Searles & Schneider 1978; Sears 1970; Taylor 1957), has hitherto not been observed on our coast. This report provides the first Canadian record of *L. orcadensis*.

Lomentaria orcadensis (Figs 1, 2)

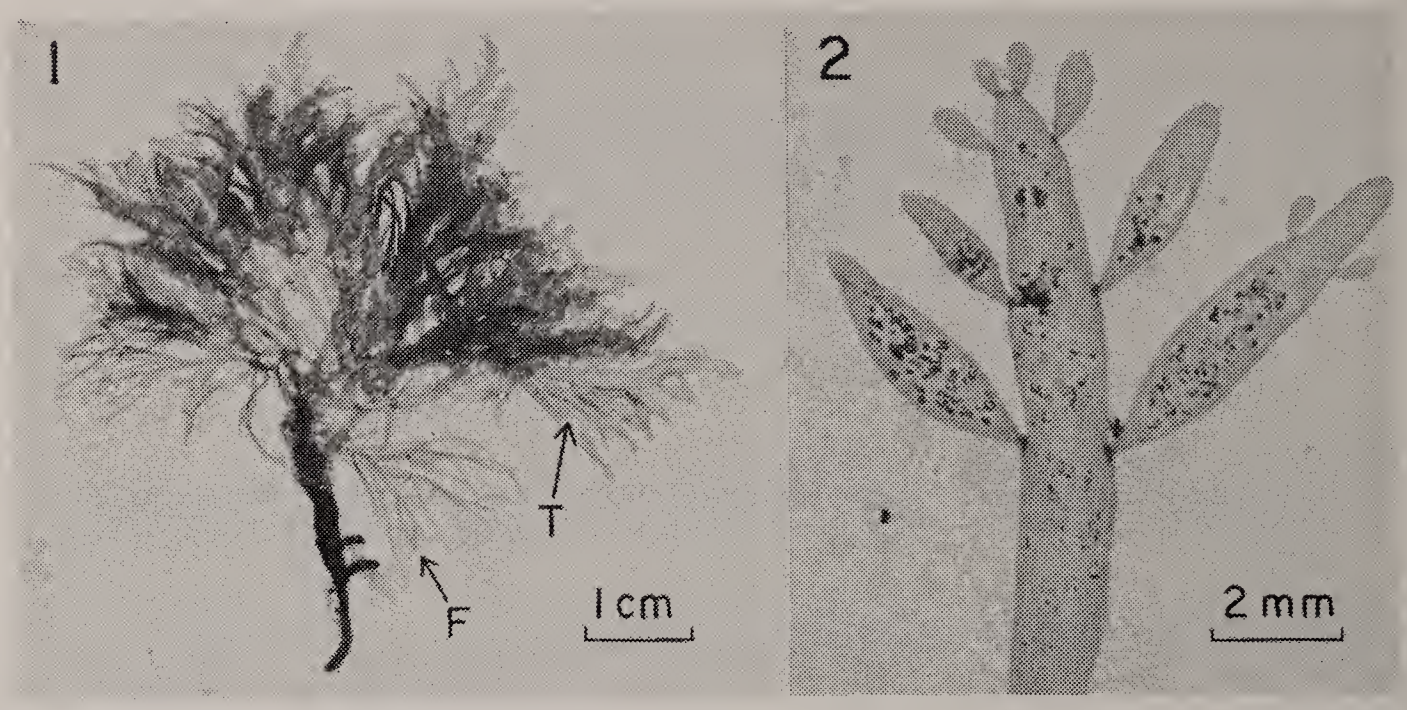
Plants densely tufted, to 3.8 cm tall, morphologically and structurally as described by Taylor (1957); frequently with localized fusion of adjacent branches; shaded branches occasionally filiform (Fig 1), later developing typical flattened morphology; all plants with tetrasporangia. On *Phyllophora truncata* (Pall.) Zinova, 8.2 m below mean sea level, Pinkney Point, Yarmouth Co., N.S. (Lat. 43°42′ N, Long. 66°04′ W), 22 August 1978. Herbarium reference: NRCC 8173.

In view of the reported distribution of *L. orcadensis* in the northwestern Atlantic (Sears 1970; Taylor 1957), it is not surprising to find this species in southwestern Nova Scotia. Rather, it is curious that *L. orcadensis* has not been observed in this area before now, particularly as it is apparently a plant of colder water than is the more familiar species, *L. baileyana*. The substantial stature of the Nova Scotian specimens suggests that the potential limit of distribution of this species in North America may lie even farther north. Moreover, the absence of sexual stages, which characterizes the northern limits of some species of Rhodophyta (Dixon 1965), is usual if not universal in *L. orcadensis* (Dixon 1973). It remains to be seen whether *L. orcadensis*, normally a rather uncommon species, is adventive in our waters.

The filiform morphology occasionally manifested in lower axes is reminiscent of *L. baileyana*. However, all instances of this phenotype displayed some localized compression of branches, transitional to the normal flattened appearance of *L. or-*

[1]*Issued as NRCC No. 17052*

cadensis. Nevertheless, it is conceivable that *L. baileyana* may coexist with *L. orcadensis* in southwestern Nova Scotia, as this area has previously yielded several other Rhodophyta with southern affinites (Edelstein et al. 1973; Wilson 1978; in herb. Atl. Reg. Lab., NRCC).



Figs 1, 2. *Lomentaria orcadensis,* NRCC 8173. Fig 1. Habit of a plant with tetrasporangia (T) and several atypical filiform branches (F). Fig 2. Enlargement of a branch with tetrasporangia, from the plant in Fig 1.

References

Dixon, P.S. 1965. Perennation, vegetative progagation and algal life histories, with special reference to *Asparagopsis* and other Rhodophyta. *Bot. Gothoburg.* 3: 67-74.

Dixon, P.S. 1973. *Biology of the Rhodophyta.* Univ. Rev. in Bot. 4. Oliver & Boyd, Edinburgh.

Edelstein, T., Bird, C., and **McLachlan, J.** 1973. Investigations of the marine algae of Nova Scotia. XI. Additional species new or rare to Nova Scotia. *Can. J. Bot.* 51: 1741-1746.

Edelstein, T., McLachlan, J., and **Craigie, J.S.** 1967. Investigations of the marine algae of Nova Scotia. II. Species of Rhodophyceae new or rare to Nova Scotia. *Can. J. Bot.* 45: 193-202.

Kylin, H. 1956. *Die Gattungen der Rhodophyceen.* C.W.K. Gleerups Förlag, Lund.

Searles, R.B. and **Schneider, C.W.** 1978. A checklist and bibliography of North Carolina seaweeds. *Bot. Mar.* 21: 99-108.

Sears, J.R. 1970. *Morphology, Systematics and Descriptive Ecology of the Sublittoral Benthic Marine Algae of Southern Cape Cod and Adjacent Islands.* Ph.D. Thesis, University of Massachussets, Amherst.

Taylor, W.R. 1957. *Marine Algae of the Northeastern Coast of North America* (revised ed.). Univ. Mich. Press, Ann Arbor.

Wilson, J.S. 1978. *The Benthic Marine Algae of the Bay of Fundy, Canada.* B. Sc. Thesis, Acadia University, Wolfville.

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A CULTURE AND CYTOLOGICAL STUDY OF THE LIFE HISTORY OF *NEMALION HELMINTHOIDES* (RHODOPHYTA, NEMALIALES)[1]

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The life history of Nemalion helminthoides (Vell. in With.) Batt. is described based on results from culture and cytology. This consists of morphologically dissimilar gametophytic and tetrasporophytic generations. The former is haploid (n=10) and the latter is diploid (2n=20), with meiosis presumably occurring in the tetrasporangium. Tetrasporogenesis was induced by increasing the temperature from 5° to 20°C. Gametophytic plants developed only under 15°C and a long duration of light, 16:8 h. Spermatia and carpogonia occurred on the same thallus.

Introduction

Aspects of the life history of species of *Nemalion* have been reported by Fries (1967), Martin (1967, 1969), Umezaki (1967a,b, 1972), and Masuda and Umezaki (1977). In common with other Nemaliales, species of *Nemalion* appear to have a heteromorphic life history, although culture studies (Fries 1967; Umezaki 1967b, 1972) have failed to re-establish the characteristic macroscopic gametophyte. Germination of tetraspores resulted only in microscopic, filamentous sporelings, but there is justification for assuming that these sporelings give rise directly to the characteristic macroscopic gametophyte thallus. Both Ramus (1969) and von Stosch (1965) found that the filamentous sporeling derived from tetraspores of *Pseudogloiophloea confusa* and *Liagora farinosa* respectively (Nemaliales) formed "buds" which initiated the macroscopic gamtophyte. Further, Masuda and Umezaki (1977) in Japan have reported on the gametophytic thallus in culture for *N. vermiculare*.

Nemalion helminthoides has been investigated cytologically by Magne (1961) who reported that the haploid number of chromosomes in the gametophyte was n=8. It was assumed that meiosis occurred during tetrasporogenesis.

On the basis of culture and cytological observation of *N. helminthoides*, we now describe the developmental sequence of the life history and chromosome counts in nuclear phases.

Materials and Methods

Gametophytic plants with carpospores (Fig 1) were collected at Martinique Beach, Halifax, Co. in 1969, 1970 and Bras d'Or Lake, Victoria Co. (McLachlan &

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Table I Conditions of incubation for induction of tetraspore formation and development of upright gametophyte. Tetrasporic filaments were maintained at 5°C, 8:16 h light prior to incubations under conditions indicated.

Temp (°C)	Light* (L:D)	Days incubation 7	14	21	28	Remarks‡
			Tetraspore release†			
5	16:8	0	0	0	0	Few monospores only
10	12:12	0	++	+++	+++	Tetraspores germinated slowly
10	16:8	+	++	++++	++++	Tetraspores germinated slowly
13	10:14	+	++	++++	++++	Tetraspores germinated slowly
15	10:14	+	+++	++++	++++	Tetraspores germinated
15	16:8	+++	+++++	+++++	+++++	Tetraspores germinated giving rise to characteristic upright fronds after 6 weeks**
20	12:12	++	++++	++++	++++	Tetraspores germinated
20	16:8	+++	+++++	+++++	+++++	Tetraspores germinated giving rise to characteristic upright fronds after 6 weeks**

* Illuminance 40 ± 15μE $m^{-2}s^{-1}$
† Visual estimation
‡ Monospores formed under all conditions
**Upright gametophytic fronds maintained growth above 10°C; 10-16-h light periods were satisfactory

Edelstein 1970-71) in 1976, both in Nova Scotia. Segments with carposporangia were brushed and cleaned in sterile seawater, and incubated at 15°C, 16:8 h (L:D) and 13°C, 10:14 h. In both cases illumination of about 20μE $m^{-2}s^{-1}$ was provided by 40-W cool-white, fluorescent lamps. After 12 h incubation, carpospores were discharged and these were transferred by finely-drawn pipettes to small (60 x 20 mm) disposable, plastic petri dishes containing SWM-3 medium (McLachlan 1973). Some sporelings were cultured in medium containing 5-10 mg $^{-1}$ of GeO_2 to suppress diatom contaminants. Individual sporelings were, at an early stage (Fig 2), re-isolated by pipette, and unialgal cultures were thus established.

Tetrasporophytic filaments were incubated under various conditions of

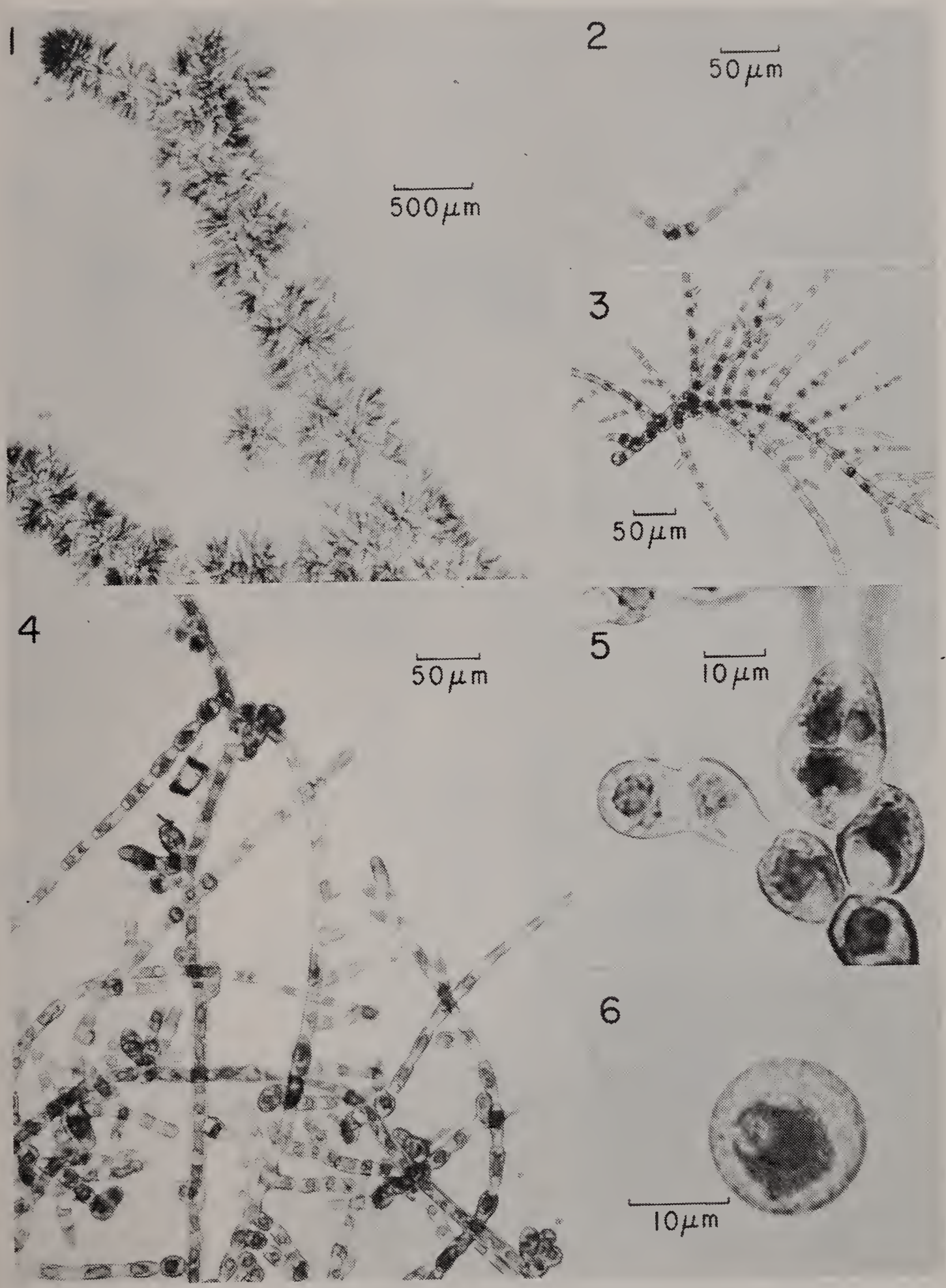
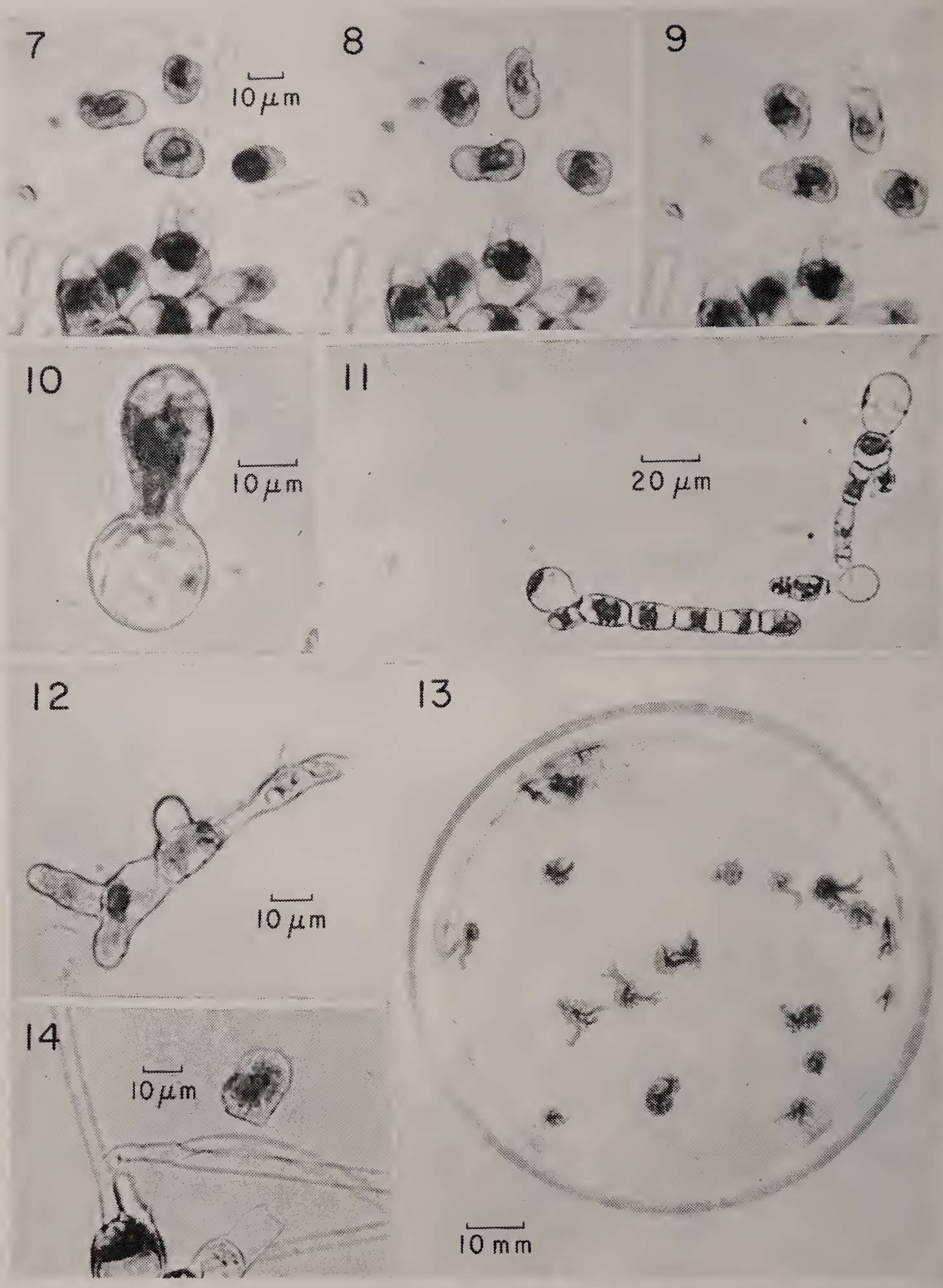
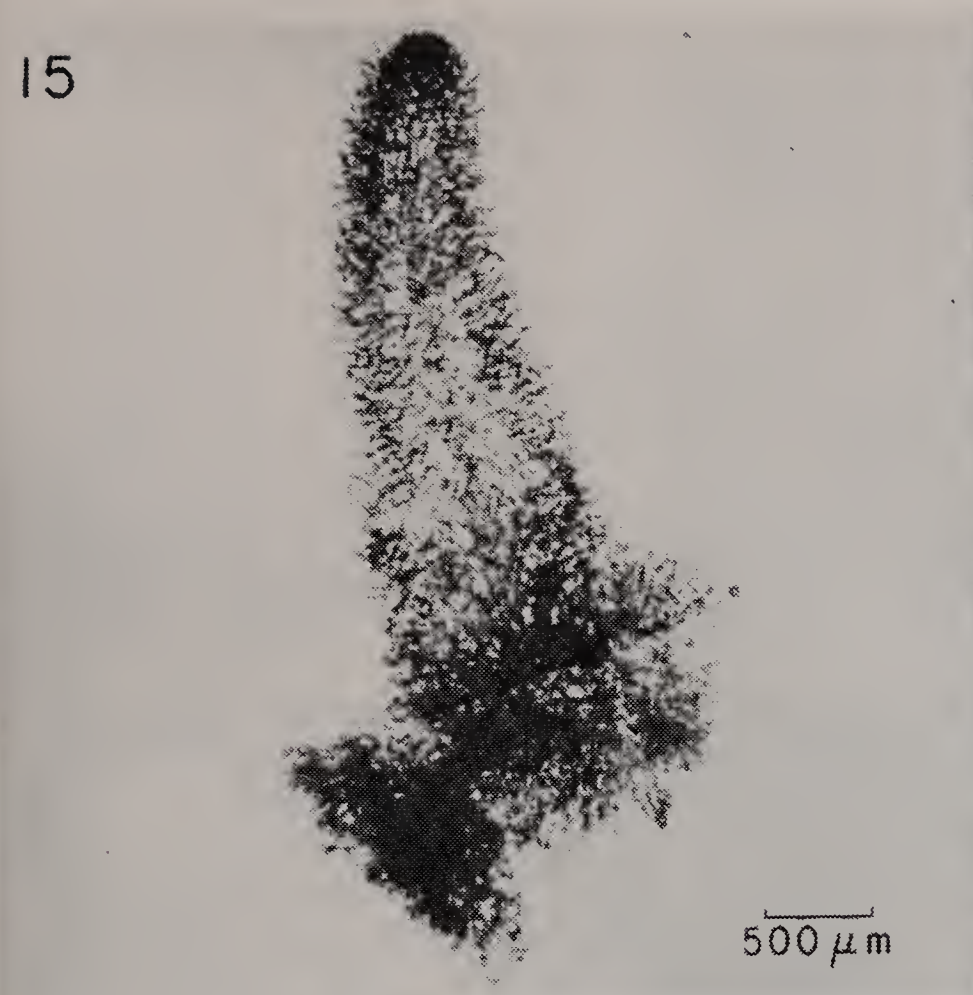
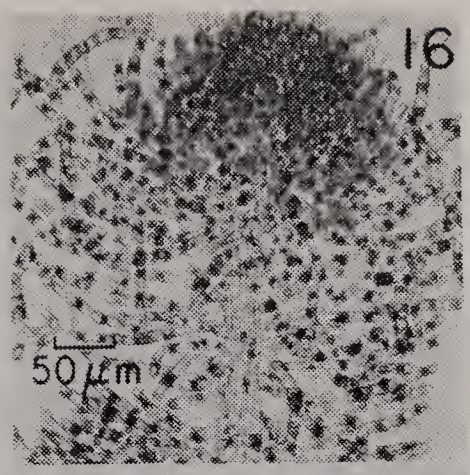


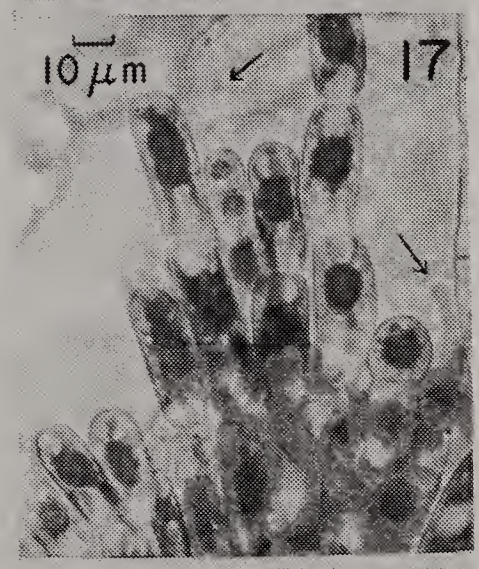
Fig 1. Portion of field-collected gametophyte. Fig 2. Filamentous tetrasporophyte from carpospore. Fig 3. Further development tetrasporophyte showing pronounced branching. Fig 4. Portion of a mature tetrasporophyte showing cruciate tetraspores within sporangia. Fig 5. Tetrasporangium showing formation of tetraspores. Fig 6. Released tetraspore.

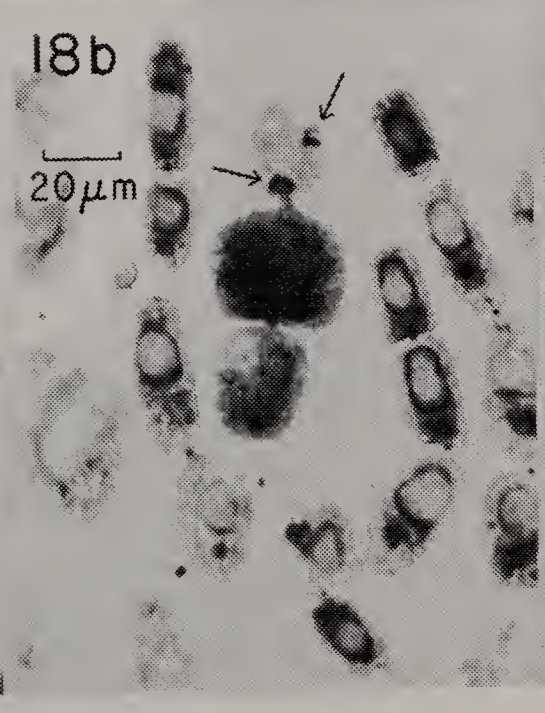


Figs 7-9. Chronological sequence of 4 tetraspores after discharge from the sporangium (10-min intervals); note amoeboid shapes. Fig 10. Germinated tetraspore with a protuberance. Fig 11. Various stages of tetraspore germination, with formation of a transverse wall and hyaline hair. Fig 12. Later stage of tetraspore germination; note the empty original cell and the intercalary branching. Fig 13. Upright gametophytic plants; from tetraspores. Fig 14. Monospore released from sporangium.









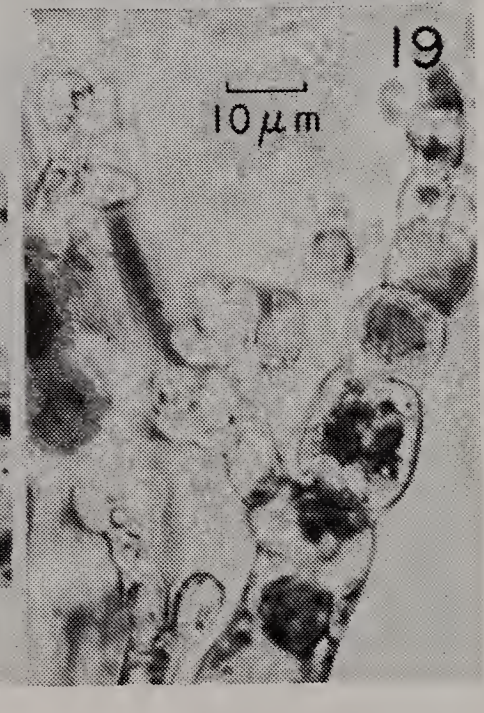
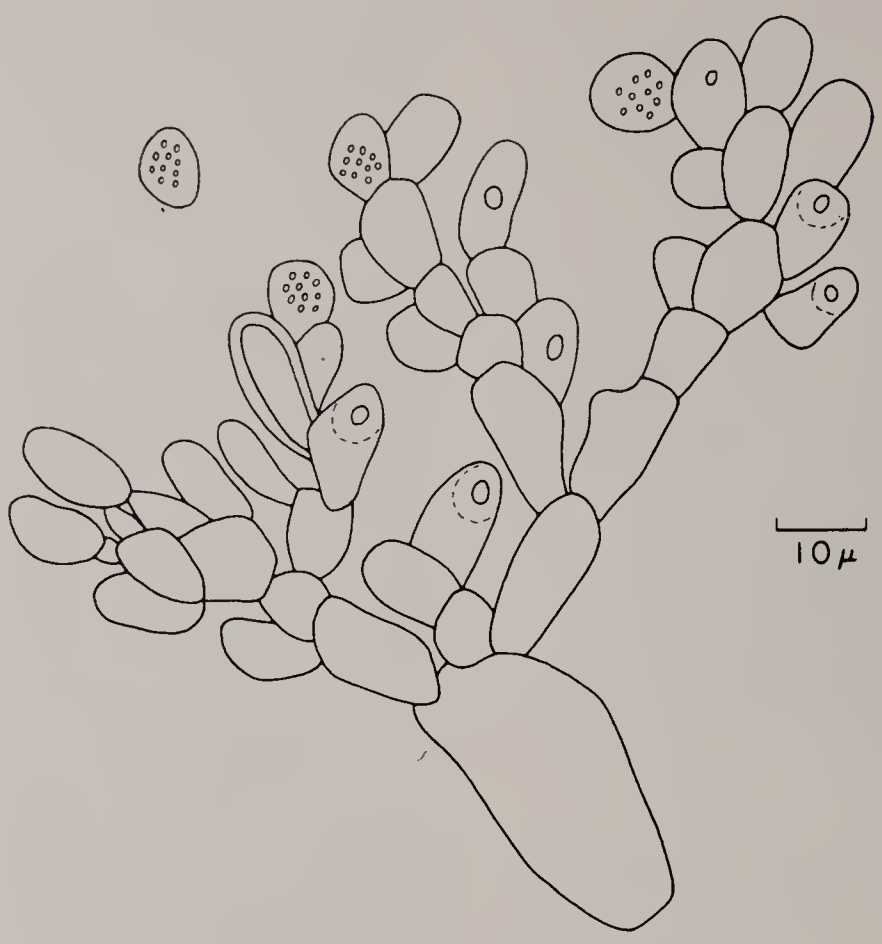


Fig 15. Gametophytic plant showing the arrangement of filaments and the discoid basal portion. Fig 16. Portion of gametophytic frond showing the apex and central axis. Fig 17. Portion of a gametophytic frond showing carpogonia. Fig 18. Mature gametophytic plant with discoid base and upright branched frond. Fig 19. Portion of a gametophytic frond showing spermatia.



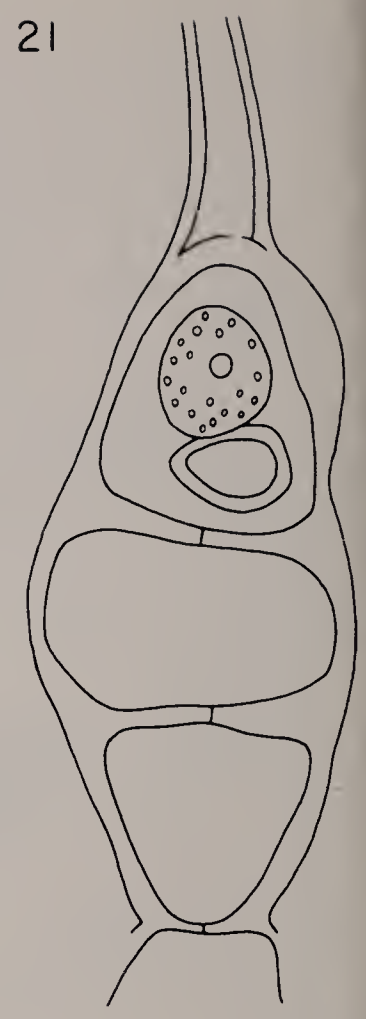


Fig 20. Chromosomes in spermatium; n=10. Fig 21. Carpogonial branch; diploid (2n=20) number of chromosomes in nucleus of carpogonium.

temperature and duration of light (Table 1). The culture medium was changed weekly. Filaments which had been maintained at 5°C, 8:16 h for 18 months were segregated into about equal portions and inoculated into small plastic dishes. Sets of 4 dishes were incubated under various conditions (Table I) for a period of 4 weeks. The medium was changed weekly and plants were observed for formation of tetrasporangia and for release of tetraspores.

For cytological studies, both field-collected gametophytic thalli bearing mature reproductive structures and cultured germlings from both tetraspores and carpospores were fixed with acetic acid ethanol (1:3), and stained with Wittmann's stain (Wittmann 1965).

Observations

Nemalion helminthoides becomes apparent in late summer, and has been reported from Prince Edward Island, Cape Breton Island, and the Atlantic coastal waters of Nova Scotia (*in herb.*). However, this species has not been reported from the Bay of Fundy (Wilson 1978).

The released carpospore was thin-walled, spherical (10-15 μm diam), and contained a single, stellate chromatophore. Soon after release, the plastid became diffuse, and the spore swelled and adhered to the substratum. Subsequently, a protuberance of the cell wall developed, into which the cytoplasm migrated, with formation of a transverse wall cutting off the original spore. In some cases a small portion of the cellular contents remained in the original spore. This type of development of the spore agrees with previous observations (Umezaki 1967a, b, 1972; Masuda & Umezaki 1977). Further development, through apical growth, resulted in a

filamentous sporeling (Fig 2) bearing hyaline hairs. Subsequently, branching occurred from intercalary cells of the filament, and within a month a mat of filamentous sporelings (Fig 3) formed on the substratum. Although we maintained these cultures for a year at various temperatures and durations of light, tetrasporangia failed to develop; monospores, however, formed with release and germination under all conditions. Results were similar with additional cultures established the following year.

Sporelings incubated under conditions in Table I were transferred to 5°C, 8:16 h for 18 months. When transferred to higher temperatures, tetrasporangia formed with 4 weeks (Table I) on lateral branches of the filamentous sporeling (Fig 4). Tetraspores, cruciately arranged (Fig 5), were released under all conditions above 5°C (Table I), with maximum release adjudged to occur above 13°C. Monospores (Fig 14), noted under all conditions of incubation, gave rise once more to tetrasporic filaments. Monospores usually were slightly larger than tetraspores, but subsequent development was the only certain means of distinguishing between these 2 types of spores.

After about a month at a higher temperature, formation of tetrasporangia was reduced considerably. In all cases, tetrasporic filaments grew well, but additional plants were formed either by monospores or by vegetative fragmentation of the filaments. Vigorous tetrasporogenesis could be induced only by returning the filaments to a relatively low (5°C) temperature for about a month, and then transferring these again to a higher temperature.

Before adhering to the substratum, discharged tetraspores (Fig 6) were amoeboid (Figs 7, 8, 9). Early development of filamentous, gametophytic sporelings (Figs 10-12) was similar to that of tetrasporic sporelings, as were the appearance of individual cells and the arrangement of cells within the filaments. Radial growth of these filaments resulted in formation of a loosely compacted base (Fig 13) which eventually became the basal holdfast of the upright gametophyte (Fig 15). A few lateral filaments in the central region of the filamentous base became compacted through outgrowths on a secondary level, thus initiating the upright frond. This, however, occurred only at 15°C to 20°C with a 16-h light period (Table I). These initial filaments became axes of fronds from which numerous, richly branched lateral filaments (Fig 16) of limited growth arose, giving the upright frond a smooth appearance (Figs 15, 16). In plants incubated in a light period of less than 16 h, irregular filamentous growth resulted.

Cells of the upright frond were rectangular (Fig 16), with central axial cells more elongated than lateral assimilative cells; hyaline hairs were occasionally formed from the latter. At this stage of development, the morphological features were characteristic of a gametophytic plant (Figs 1, 15, 18). Mature gametophytes, either branched or unbranched (Figs 13, 18), arose from the same parental material. Growth of the upright gametophyte took place under various conditions, although below 15°C filaments soon exhibited disordered growth of the assimilative cells.

After 2 months of incubation at 15°C, 16:8 h and 20°C, 16:8 h, gametophytes became fertile, spermatia (Fig 19) being produced on lateral branchlets of limited growth. Following an additional period of 6 weeks, these same plants formed carpogonial filaments (Fig 17) indicating that they were monoecious. The same results were obtained 3 times during the course of this study, yet the carposporophyte was not formed. During a further 6 weeks in culture, the plants deteriorated. In addition, plants exhibiting irregular filamentous growth developed spermatia after 4 months at 20°C, 12:12 h.

Cytological results showed that the haploid number of chromosomes was $n=10$ in somatic cells of gametophytes, spermatangia (Fig 20), and sporelings started from tetraspores. The diploid number of chromosomes was $2n=20$ as recorded in division of the nucleus within the carpogonium, and in sporelings from carpospores (Fig 21).

Discussion

In culture, the life history of *N. helminthoides* consists of a sequence of carpospore, microscopic filamentous tetrasporophyte, tetraspore, and macroscopic gametophyte which is presumably monoecious. Our cytological evidence indicates that meiosis occurs in the tetrasporangium. Previous investigators working with this species in culture were unsuccessful in obtaining the characteristic gametophytic phase from tetraspores (Fries 1967, 1969). However, Fries (1967) obtained abnormal thalli from tetraspores, and these formed what she believed to be young carpogonia. In our case gametophytes continued normal growth only under relatively high temperature (15° - 20°C) and long photoperiod (≈16h), or essentially summer conditions at our latitude. This could explain why *N. helminthoides* has not been recorded in the Bay of Fundy, where temperatures do not reach 15°C except in muddy areas at the head of the Bay.

The upright gametophyte was initiated from a group of compacted filaments in the center of the loosely formed filamentous base. This mode of development is somewhat different from that of *Liagora farinosa* and *Pseudogloiophloea confusa* in which erect gametophytic thalli formed from buds on the filamentous sporeling.

Both spermatia and carpogonial filaments were formed on the same gametophytic thallus; thus, this species is monoecious. But in culture these structures did not occur simultaneously, and moreover we were unable to obtain formation of the carposporophyte. This may indicate a lack of fertilization of the carpogonium, or possibly conditions of culture were unfavorable for development of the carposporophyte.

Tetrasporangia formed under various conditions of temperature and photoperiod. However, a prior excursion into low (5°C) temperature and short (8 h) photoperiod was necessary to induce sporogenesis and these may be regarded essentially as winter conditions. Quite probably carpospores formed during late summer and autumn give rise to the microscopic tetrasporophyte, which, in turn forms tetrasporangia in spring with increasing temperature and daylength (Söderström 1970). *Nemalion helminthoides* recurs year after year at the same sites, suggesting perennation by the tetrasporophyte. Furthermore, we have experienced no problem in maintaining this phase in culture for many years. Both Fries (1969) and Martin (1969) have reported on the occurrence of the tetrasporophyte in nature. Neither observed tetrasporangia in field-collected material, and Martin noted that the erect gametophyte seemed to arise directly from presumed gametophytic filaments. She further suggested that perennation may occur through the prostrate gametophytic filament.

Monospores commonly were formed on tetrasporic filaments under all conditions of temperature and photoperiod, and in addition to vegetative fragmentation, propagated this phase. Formation of monospores by the tetrasporophyte in culture has been noted previously by both Fries (1967) and Umezaki (1967a, b, 1972). We also observed monospore formation by the filamentous gametophytic sporeling as noted for *Pseudogloiosphlea confusa* (Ramus 1969).

Acknowledgement

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References

Fries, L. 1967. The sporophyte of *Nemalion multifidum* (Weber et Mohr) J. Ag. *Sven. Bot. Tidskr.* 61: 457-462.

Fries, L. 1969. The sporophyte of *Nemalion multifidum* (Weber et Mohr) J. Ag. found on the Swedish west coast. *Sven. Bot. Tidskr.* 63: 139-141.

Magne, F. 1961. Sur le cycle cytologique du *Nemalion helminthoides* (Velley) Batters. *C.R. Acad. Sci.* Ser. D, 252: 157-159.

Martin, M.T. 1967. Observations on the life history of *Nemalion helminthoides* (Vell. in With.) Batt. *Br. Phycol. Bull.* 3: 408.

Martin, M.T. 1969. A review of life-histories in the Nemalionales and some allied genera. *Br. Phycol. J.* 4: 145-158.

Masuda, M. and **Umezaki, I.** 1977. Life history of *Nemalion vermiculare* Suringar (Rhodophyta) in culture. *Bull. Jpn. Soc. Phycol.* 25, (Suppl.): 129-136.

McLachlan, J. 1973. Growth media-marine. In: *Handbook of Phycological Methods* (*ed* J.R. Stein), Cambridge University Press, Cambridge. pp. 25-51.

McLachlan, J. and **Edelstein, T.** 1970-71. Investigations of the marine algae of Nova Scotia. IX. A preliminary survey of the flora of Bras d'Or Lake, Cape Breton Island. *Proc. N.S. Inst. Sci.* 27: 11-22.

Ramus, J. 1969. The developmental sequence of the marine red alga *Pseudogloiophloea* in culture. *Univ. Calif. Publ. Bot.* 52: 1-42.

Söderström, J. 1970. Remarks on the European species of *Nemalion*. *Bot. Mar.* 13: 81-86.

Umezaki, I. 1967a. The tetrasporophyte of *Nemalion vermiculare* Suringar. *Rev. Algol.* 9: 19-24.

Umezaki, I. 1967b. On a microscopic phase in the life cycle of *Nemalion pulvinatum* Grunow (Nemalionaceae, Rhodophyta). *Publ. Seto Mar. Biol. Lab.* 15: 311-318.

Umezaki, I. 1972. The life histories of some Nemaliales whose tetrasporophytes were unknown. In: *Contributions to the Systematics of Benthic Marine Algae of the North Pacific* (*ed* I.A. Abbott & M. Kurogi), Japanese Society of Phycology, Kobe. pp. 231-242.

Von Stosch, H.A. 1965. The sporophyte of *Liagora farinosa* Lamour. *Br. Phycol. Bull.* 2: 486-496.

Wilson, J.S. 1978. *The Benthic Marine Algae of the Bay of Fundy, Canada*. BSc (Honours) Thesis. Acadia University, Wolfville, N.S.

Wittmann, W. 1965. Aceto-iron-haematoxylin-chloral hydrate for chromosome staining. *Stain Technol.* 4: 161-164.

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DIATOM STRATIGRAPHY OF BASIN HEAD HARBOUR PRINCE EDWARD ISLAND

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Diatoms have not been exploited to date in studies of changes in the coastal environments of Atlantic Canada. A core of estuarine sediments, 836 cm long, from Basin Head Harbour, Prince Edward Island, was found to contain diatoms representing various salinity preference ranges. The microfossil populations in the cored sediments contain 102 distinguishable taxa which were analysed statistically and interpreted. The lowest sediments which contain freshwater diatoms have radiocarbon dates of 4,185 ± 85 B.P. at the base and 3,370 ± 135 B.P. at 733 to 738 cm core depth. Abundant marine and brackish water diatoms appear at about 600 cm core depth and they decline markedly in frequency above the 287 cm level. A drowned tree stump retrieved from a nearby salt marsh was dated at 1,050 ± 90 B.P. A rapid postglacial marine transgression is inferred and a contemporary submergence rate of about 3.6 to 10.2 cm/century is calculated.

Introduction

In Atlantic Canada, several studies have elucidated the general trends of postglacial changes in sea level (Grant 1970, 1972, 1975; Kranck 1972; Wightman & Cooke 1978). The information used in interpretation has been based variously on: conventionally dredged marine sediments, drowned forests, uplifted marine terraces, and mooring rings inappropriately disposed relative to contemporary mean sea level. Many of these data available have been derived (with known error limits) from the fortuitous retrieval of materials usually datable by radiocarbon analysis. The most useful information is that which incorporates both a geologically significant stratigraphic marker and an associated date. Many attempts at obtaining material in the coastal zone which meet both of these criteria have been unsuccessful.

Diatoms have unexploited potential as geologically significant stratigraphic markers with respect to changing sea level. The frustules of these small siliceous (and thus relatively resistant) microflora have been found well-preserved in estuarine sediments and record with fidelity the changing salinity of the aquatic environment (and by implication changing sea level) at a given site. Some of the reasons for their value are:

1. Ubiquity in natural aquatic environments (fresh and salt water).
2. Salt specificity of many diatom species.
3. Relative resistance to chemical alteration (after burial).
4. Preservation along with other organic material, some of which is carbonaceous and therefore is datable.

Salinity preferences of different diatom species have been recognized since the last century and can be applied to the studies of sea level change.

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Basin Head Harbour

At Basin Head Harbour, Prince Edward Island, an uncommon ridged sand deposit now protects a lagoon and salt marsh environment (Fig 1). The area is partly covered by spruce and fir growing on the ridge crests slightly above higher-high water datum while salt marsh plants occupy the valleys. Geomorphological evidence suggests that deposition of these reworked sands is related to postglacial marine transgression (Crowl 1969; Prest 1973). Contemporary processes are eroding the deposit as evidenced by: a) the altered beach outline and associated disappearance of fishing huts; and b) the truncated arcuate ridges shown in the photomosaic (cf. Fig 1 and Fig 2).

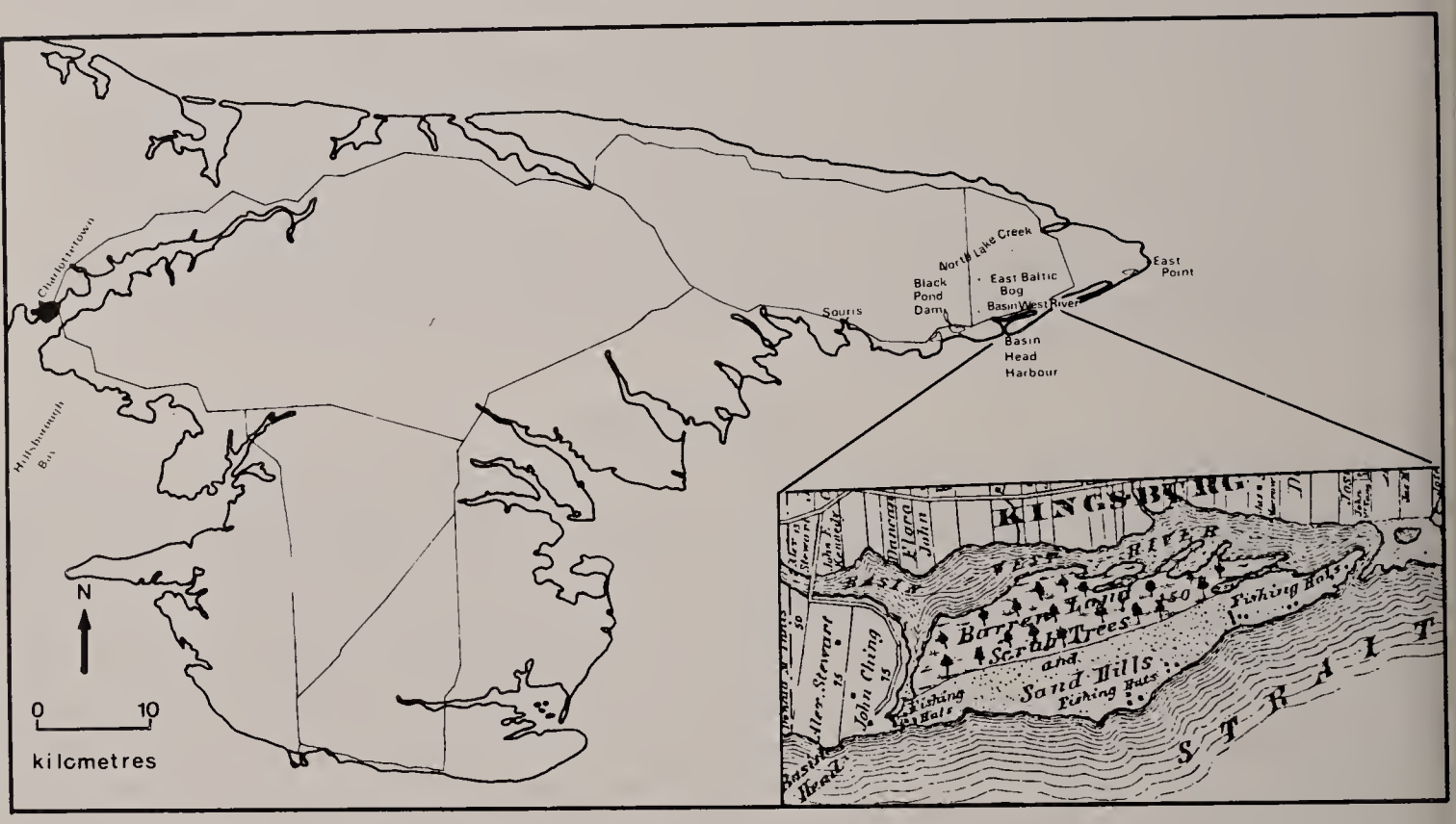


Fig 1. General location map of eastern Prince Edward Island showing Basin Head Harbour near the eastern extremity. The inset map is extracted from a land ownership map compiled in the last century. Note the "Fishing Huts" on the beach, and the outlet of Basin West River.

Fig 2. Photomosaic of Basin Head Harbour showing sand ridges, the coring site, and the site of a drowned tree stump all noted in the text.

The underlying bedrock configuration was established from the results of hammer seismic and resistivity observations (Fig 3); however, there is not a strong relationship between the surface expression of the deposit and the buried bedrock surface.

Examination of test pits in the sand ridges and samples in the laboratory failed to reveal any good evidence with which to determine the time or mode of deposition. The search for such information was extended to include undisturbed areas of the salt marsh and lagoon. Both areas furnished indirect evidence related to the depositional history of the Basin Head study area.

The ridges adjacent to the lagoon are low-lying and have the least amplitude of those in the whole deposit; salt marsh peat has filled in the swales to maxiumum depth of 1 m. One of several stumps occurring in growth position was retrieved from a small drainage channel in this salt marsh. It had a known 'root crown' elevation of 41 to 98 cm below the local higher-high water mark. The exhumed stump was radiocarbon dated at 1050 ± 90 B.P. (DAL 27b, Ogden & Hart 1976). The age of this tree stump gives the youngest possible date for ridge formation prior to the growth and death of the spruce tree which was presumably killed by tidal flooding of the area.

It is known from local history that dredging was conducted in 1937-1938 for the benefit of local fishermen. The distal outlet of Basin West River (Fig 1) was closed and the proximal inlet was created artificially (Fig 2). There is no field evidence for an earlier inlet at this location.

A site for sampling estuarine sediments remote from areas of human disturbance was selected (Fig 2). At this site, a Livingstone Corer was used to retrieve 836 cm of estuarine sediments 3 m below a stable ice surface in mid-winter. It was necessary to use silicone grease as a lubricant to isolate the brass and aluminum components of the corer in the brackish lagoon and to preclude hydrocarbon (grease) contamination of potentially datable radiocarbon material.

Laboratory Observations and Methods

In the laboratory, the core was found to have 3 gross color and textural features: a) RED MUD (10YR 2/2) - about 650 to 836 cm; b) GREEN MUD (5YR 3/2) - about 300 to 650 cm; and c) organic BROWN CLAY (10YR 3/2) - 000 to 300 cm. These and other macroscopic characteristics are illustrated in Figure 4.

Reconnaissance samples were extracted at 50 cm intervals and examined for sedimentological characteristics and microfossil content. Diatom frustules were discovered in abundance and dissimilar microfossil spectra implied that detailed population analysis would be worthwhile (Fig 5).

An examination of the literature showed that diatoms had been used previously in pertinent paleoecological studies (Foged 1970), but that a sound statistical and universal approach to sampling and population analysis apparently did not exist (Setty 1966; VanLandingham 1967, 1970; Hecky & Kilham 1973).

The sampling and mounting technique eventually employed was based on that described by Smith (1873). The Fleet counting method was used, well known to geologists for the counting of microscopic mineral grains (Galehouse 1971) and an 'ideal' optimum of 300 individual frustules was counted in each sample. Some 68 samples were prepared from various levels in the core. The specimens that were not identifiable during counting were later allocated either to identifiable taxonomic groups or to a category of 'unknowns'. All the statistics used incorporated the 'unknowns' including unrecognizable diatom specimens represented by at least half a frustule.

Fig 3. Map of calculated depths to bedrock below higher high water as determined by hammer seismic refraction and Schlumberger resistivity soundings. Bedrock isobaths are included to show the inferred configuration of bedrock topography.

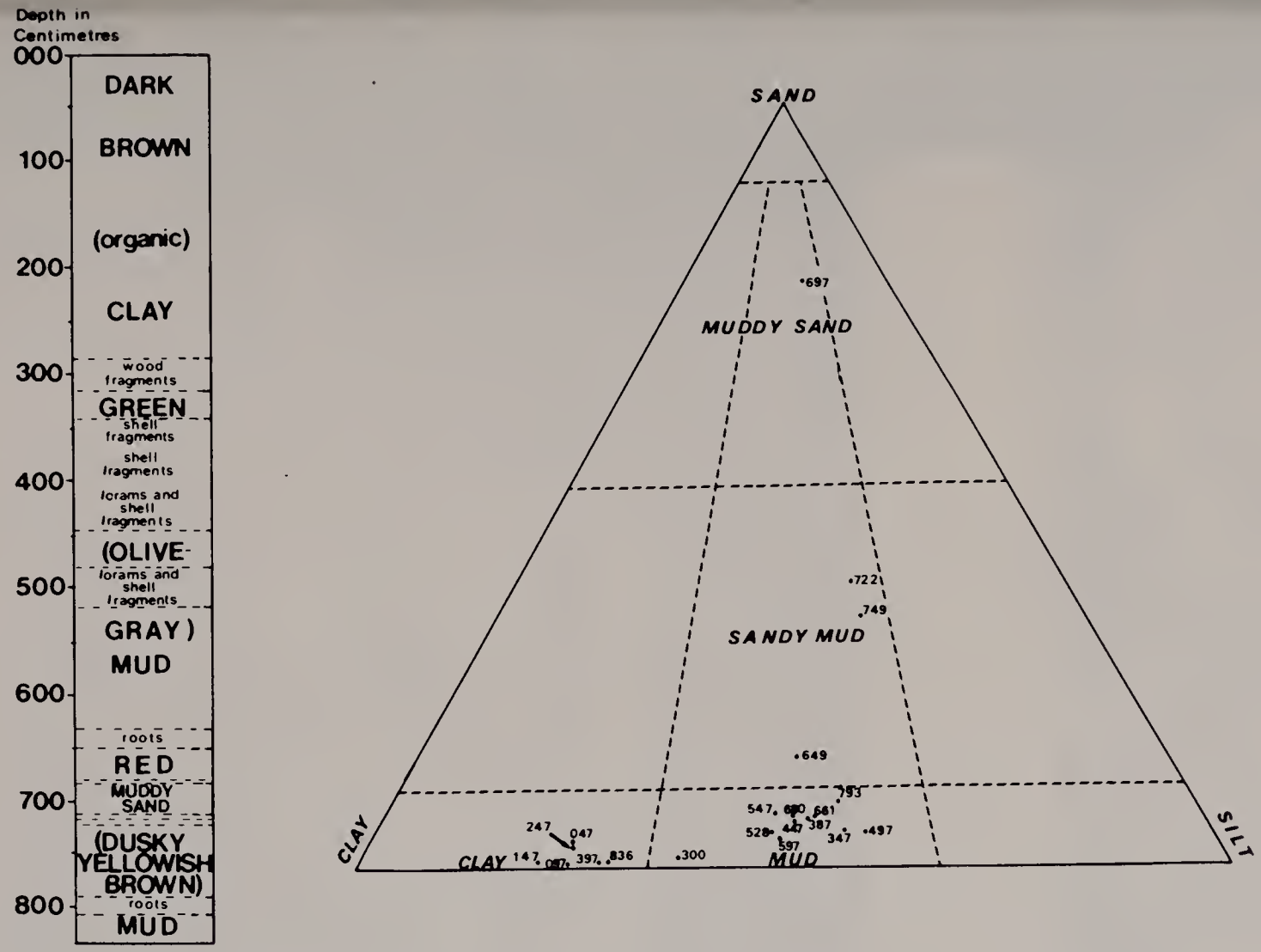


Fig. 4 Stratigraphic column and triangular diagram showing proportions of sand, silt, and clay determined in sediment samples extracted from the core. Numbers indicate the depth in core expressed in cm from top. Note the root and wood fragment layers between: the Dark Brown Clay and Green Mud at about 300 cm, and the Green Mud and Red Mud at about 600 cm.

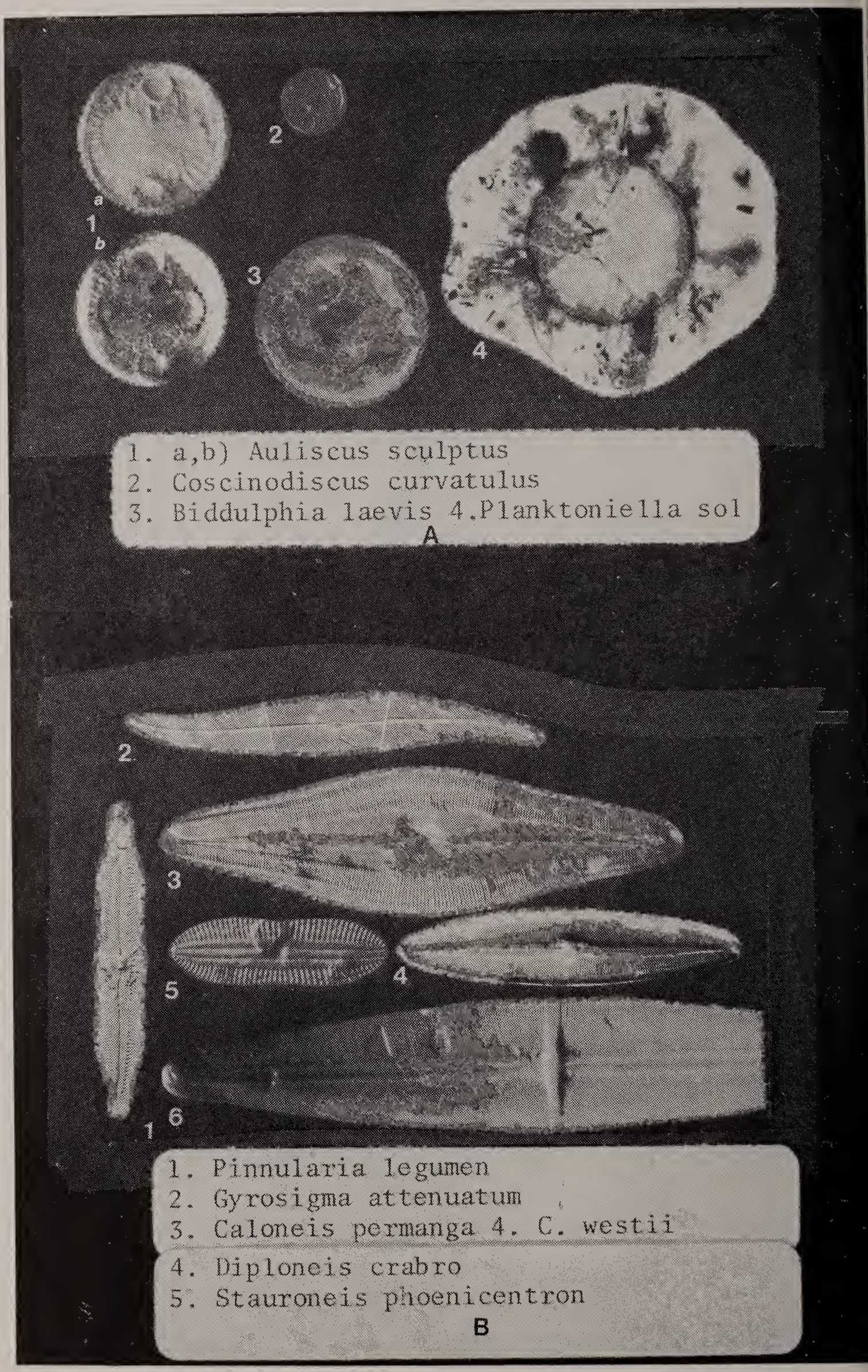


Fig 5. Diatoms in sediments from Basin Head Harbour.

Diatom Analysis and Stratigraphy

One hundred and two taxonomic groups were identified (Table I) and the habitat preferences for the various taxa were compiled from 2 sources: a) the ecological reports in the literature (e.g. Cleve-Euler 1951-1955: Frenguelli 1938-1943: Hustedt 1930-1966: Hendey 1964: Patrick & Reimer 1966); and b) a reference sample collected from a contemporary freshwater environment at Black Pond Dam (Fig 1).

The various taxa from each stratigraphic level were assigned to one of several 'Halobian' (salt sensitivity) habitat categories listed as follows: a) 'Oligohalobian' (freshwater); b) 'Euryhaline' (Oligohalobian) (taxa tolerant of increased salinity but nominally freshwater); c) 'Mesohalobian' (brackish water); d) 'Euhalobian' (marine); and e) 'Unknowns' (both unidentifiable specimens and those of uncertain salinity preferences). A distribution chart was prepared to illustrate how the proportions of halobian categories varied throughout the core. This chart (Fig 6) is based upon the relative frequencies (i.e. percentages of the various halobian categories at any given stratigraphic level and show the probable error range of the observed relative frequencies at the 95% level of confidence computed according to the formula (Galehouse 1971):

$$E_{95} = 1.96 \sqrt{\frac{P(100-P)}{N}}$$

Where: E_{95} is the probable error of the observed frequency in percent (%) at the 95% confidence limit, and 1.96 is the number of standard deviations from the mean in the 'normal' sampling distribution associated with E_{95}.

P is the percentage in a category, and N is the total sample population counted at a given level.

The distribution chart (Fig 6) was then used for a paleoecological reconstruction based upon the premise that the variations in Halobian categories represent population changes responding to alterations in habitat.

The core can be broadly subdivided into 3 stratigraphic levels, identified here for simplicity as Lowest Zone (600-836 cm), Middle Zone (287-600 cm), and Highest Zone (000-287 cm). The 2 zonal boundaries at about 600 and 287 cm core depth are based on the significant fluctuations in the 'Mesohalobian' and 'Euhalobian' categories. There is a general agreement between the biozone boundaries at 600 and 287 cm core depth and the gradational contacts between the Red and Green Mud and the Green Mud and Brown Clay of the cored sediments.

In the Lowest Zone, the 'Euryhaline' (Oligohalobian) and 'Oligohalobian' diatoms dominate. The relative frequencies of 'Mesohalobian' and 'Euhalobian' taxa are collectively very low in this zone, rarely exceeding a few percentage points. A sand layer (690-730 cm) with gradational contacts is notably coarser than the red mud typical of this zone and contained relatively far fewer diatom frustules. The lower absolute numbers counted in preparations are reflected in very high Probable Errors on the counts of 'Oligohalobian' diatoms. Neither 'Mesohalobian' nor 'Euhalobian' forms were observed within the counted samples.

The Middle Zone is markedly different from the Lowest Zone in that 'Mesohalobian' and 'Euhalobian' forms show a persistent and gradual increase in relative frequencies until maxima are reached at the uppermost level of the zone (287 cm) Both the 'Euryhaline' (Oligohalobian) and 'Oligohalobian' taxa manifest a concomitant decline in relative frequencies in this zone. The 'Unknowns' are most frequent in this zone. The sediments of this zone are mainly green muds containing some foraminifera and shell fragments in addition to 'Mesohalobian' and 'Euhalobian' diatoms.

Table I

1. *Melorisa juergensii* Agardh (E)
2. *Paralia sulcata* (Ehrenberg) Cleve (E)
3. *Cyclotella meneghiniana* Kützing (O)
4. *Cyclotella kutzingiana* (Thwaites) Chauvin (O)
5. *Cyclotella stylorum* Brightwell (E)
6. *Cyclotella caspia* Grunow (M)
7. *Stephanodiscus hantzchii* Grunow (O)
8. *Stephanodiscus astrea* (Ehrenberg) Grunow var. *minutula* (Kützing) Grunow (O)
9. *Coscinodiscus marginatus* Ehrenberg (E)
10. *Coscinodiscus eccentricus* Ehrenberg (E)
11. *Actinoptychus senarius* (Ehrenberg) Ehrenberg (E)
12. *Biddulphia obtusa* (Kützing) Ralfs (E), *Biddulphia laevis* Ehrenberg (M-E)
13. *Diatoma tenue* var. *elongatum* (Lyngbye) (O-M)
14. *Meridion circulaire* (Greville) Agardh var. *circulaire* (O)
15. *Opehora martyi* Héribaud var. *martyi* (O)
16. *Fragilaria capucina* var. *mesolepta* Rabenhorst (O)
17. *Fragilaria vaucheriae* (Kützing) Petersen var. *vaucheriae* (O)
18. *Fragilaria leptostauron* (Ehrenberg) Hustedt var. *leptostauron*, var. *rhomboides* (Grunow) Hustedt, var.*dubia* (Gruno
19. *Fragilaria leptostauron* var. *leptostauron* f. *minuta* A. Cleve-Euler (O)
20. *Fragilaria construens* var. *construens* (Ehrenberg) Grunow (O)
21. *Fragilaria construens* var. *binodis* (Ehrenberg) Grunow (O)
22. *Fragilaria construens* var. *venter* f. *pusilla* Grunow, *F. elliptica* Schumann (O)
23. *Fragilaria producta* (Lagerstedt) Grunow (O)
24. *Fragilaria pinnata* var. *pinnata* Ehrenberg (O)
25. *Fragilaria pinnata* var. *minutissima* (Grunow) A. Cleve-Euler (O)
26. *Fragilaria pinnata* var. *intercedens* (Grunow) Hustedt (O)
27. *Fragilaria brevistriata* Grunow (O)
28. *Fragilaria lapponica* Grunow (O)
29. *Fragilaria atomus* Hustedt (O-M)
30. *Synedra socia* Wallace (O)
31. *Synedra fasciculata* (Agardh) Kützing (O-M)
32. *Synedra pulchella* Ralfs *ex* Kützing (O-M)
33. *Licmophora* sp., *L. abbreviata* Agardh? (E)
34. *Raphoneis amphiceros* (Ehrenberg) Ehrenberg (E)
35. *Raphoneis surirella* var. *australis* Petit (E)
36. *Grammatophora oceanica* (Ehrenberg) Grunow (E)
37. *Acnanthes affinis* Grunow (O)
38. *Acnanthes biassolettiana* Kützing, var.? (O-(M?))
39. *Acnanthes brevipes* Agardh (M-E)
40. *Acnanthes exigua* Grunow var. *heterovalva* Krasske (O)
41. *Acnanthes haukiana* Grunow var. *haukiana* (M)
42. *Acnanthes lanceolata* (de Brébisson) Grunow and varieties (O)
43. *Acnanthes linearis* (Wm. Smith) Grunow (O(halophobe))
44. *Acnanthes peragalli* Brun et Héribaud (O)
45. *Acnanthes levanderi* Hustedt (O)
46. *Cocconeis placentula* Ehrenberg, and varieties (O)
47. *Cocconeis scutellum* Cleve, var. *parva* Grunow, *Cocconeis stauroneiformis* (Van Heurck) Okuno (M)
48. *Cocconeis pediculus* var, *baltica* (Juhlin-Dannfelt) Cleve (O-M)
49. *Cocconeis* sp.

50. *Rhoicosphenia curvata* (Kützing) Grunow *ex* Rabenhorst (O)
51. *Navicula salinarum* Grunow (M)
52. *Navicula halophila* (Grunow) Cleve (M)
53. *Navicula peregrina* (Ehrenberg) Kützing (M)
54. *Navicula vulpina* Kützing (O)
55. *Navicula integra* (Wm. Smith) Ralfs (O)
56. *Navicula cuspidata* (Kützing) Kützing (O)
57. *Navicula lyra* var. *subelliptica* Cleve (E)
58. *Navicula cryptocephala* Kützing (O-M), and var. *veneta* (Kützing) Rabenhorst (M-O)
59. *Navicula rhycocephala* Kützing (O-M), and var. *germainii* (Wallace) Patrick (O)
60. *Navicula ramosissima* (Agardh) Cleve (E)
61. *Navicula digito-radiata* (Gregory) Ralfs *ex* Pritchard (E)
62. *Navicula seminulum* Grun. (O-M)
63. *Navicula distans* (Wm. Smith) *Schmidt* (E)
64. *Navicula incerta* Grunow *ex* Van Heurck (E)
65. *Navicula barbarica* Hustedt (O)
66. *Caloneis fusoides* Grunow (E)
67. *Mastogloia smithii* Thwaites *ex* Wm. Smith (M)
68. *Mastogloia pumila* (Grunow) Cleve (M)
69. *Pinnularia maior* (Kützing) Rabenhorst (O)
70. *Pleurosigma angulatum* (Quekett) Wm. Smith (M)
71. *Gyrosigma balticum* (Ehrenberg) Cleve (M-E)
72. *Gyrosigma attenuatum* (Kützing) Rabenhorst (O)
73. *Gyrosigma obscurum* (Wm. Smith) Griffith and Henfrey (M), *G. fasciola* (Ehrenberg) Griffith and Henfrey (M)
74. *Amphiprora decussata* Grunow var. *gigantea* (E)
75. *Amphiprora alata* (Ehrenberg) Kützing (M)
76. *Trachyneis aspera* (Ehrenberg) Cleve (E)
77. *Amphipleura rutilans* (Trentepohl) Cleve (M)
78. *Amphipleura micans* (Lyngbye) Cleve (E)
79. *Diploneis interrupta* (Kützing) Cleve var. *clancula* (Schmidt) Cleve? (E)
80. *Diploneis smithii* (de Brébisson) Cleve (M-E)
81. *Gomphonema parvulum* (Kützing) Grunow (O)
82. *Gomphonema lanceolatum* Ehrenberg (O)
83. *Cymbella ehrenbergii* Kützing (O)
84. *Cymbella cistula* (Hemprich) Grunow, and var. *maculata* (Kützing) Van Heurck (O)
85. *Amphora angusta* var. *ventricosa* (Gregory) Cleve (E)
86. *Amphora ovalis* Kützing, var. *affinis* Grunow? (O-M)
87. *Amphora coffeaeformis* Agardh (M)
88. *Amphora* sp.
89. *Epithemia argus* Kützing (O)
90. *Epithemia sorex* Kützing (O-M)
91. *Epithemia turgida* (Ehrenberg) Kützing (O-M)
92. *Rhopalodia gibberula* (Ehrenberg) O. Müller (M-E)
93. *Nitzschia tryblionella* Hantzsch (M)
94. *Nitzschia panduriformis* Gregory var. *minor* Grunow (E)
95. *Nitzschia apiculata* (Gregory) Grunow (E)
96. *Nitzschia socialis* Gregory (E)
97. *Nitzschia frustulum* (Kützing) Grunow (M), and varieties (O-M)
98. *Nitzschia frustulum* var. *perpusilla* (Rabenhorst) Grunow (O-M)
99. *Nitzschia fonticola* Grunow (O)
100. *Nitzschia* sp.
101. *Surirella ovata* Kützing (M)
102. *Surirella striatula* Turpin (M)

O = Oligohalobian
M = Mesohalobian
E = Euhalobian

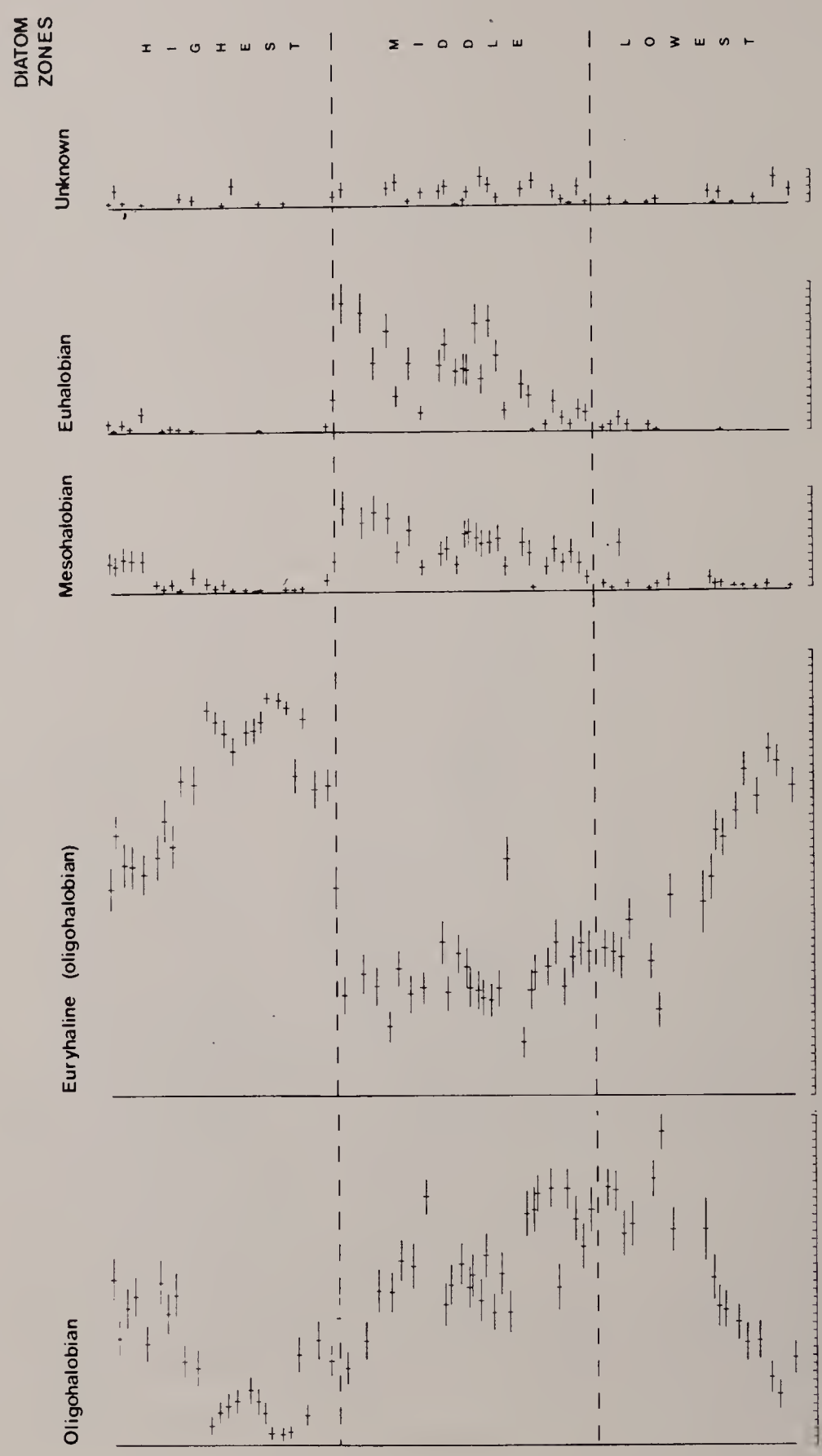


Fig 6. Distribution of components of various fossil diatom populations found at various levels within core of estuarine sediments at Basin Head; 'crosses' show the Probable Error range on relative frequencies at 95% level of confidence.

The boundary between the Middle and Highest Zone is quite remarkable because within about 10 cm the 'Mesohalobian' and 'Euhalobian' taxa decline to barely perceptible relative frequencies. Aside from a minor persistent occurrence of 'Mesohalobian' diatoms near the top of the core, the brackish and marine forms have effectively disappeared. The abundant 'Euryhaline' (Oligohalobian) and 'Oligohalobian' forms are preserved in a dark-brown (organic) clay.

Discussion

The sediments deposited in the Basin Head Harbour study area constitute a record of the Holocene rise in sea level and of coastline development.

The ridge system, which is a relatively large sand deposit, records a uniform constructional process. The absolute time required for construction of the individual ridges (which must be earlier than the growth of the dated tree) cannot be determined directly because datable material is not available. The contemporary littoral processes active at the shore are essentially responsible for erosion and modification, and therefore are not informative concerning constructional processes active there in the past. Paleoenvironmental information is, however, available from the adjacent estuary.

As indicated in Figure 4, roots and fibrous material were found in the Lowest Zone of the core of estuarine sediments. Two samples were removed for radiocarbon analysis and yielded dates of 4,185 ± 85 B.P (DAL 182) and 3,370 ± 135 B.P. (DAL 95) at the 835 to 827 cm and 738 to 733 cm levels respectively (Ogden & Hart 1976).

The lowest Zone (600-836 cm), now dated, generally contains an abundance of fossil freshwater microflora. Some saline forms occur in sample populations which clearly represent the habitat at the site of deposition; an exception may be with the sand lens where only low relative frequencies of robust freshwater forms were observed. These taxa probably represent allochthonous populations transported and deposited during a single fluvial event and preserved within the anomalous coarse (muddy sand) detritus at 690 to 730 cm core depth. The paucity of mesohalobes and euhalobes strongly suggests that the fine-grained sediments and associated 'Oligohalobian' diatoms accumulated in quiet freshwater, above the influence of seawater. Thus, sea level (represented by higher-high water) was below the base of the core at the time of deposition; about 4,200 radiocarbon yr ago, higher-high water was at least 11.4 m lower than at present (3.0 m water column + 8.4 m sediment). If constant sedimentation is assumed except for the 'instantaneous' deposition of the sand lens, the top of the zone is dated by extrapolation at 1,415 B.P.

At the zone boundary - 600 cm core depth - the onset of marine influences is detected by the statistically significant occurrence of both 'Mesohalobian' and 'Euhalobian' diatoms. Their respective relative frequencies increase steadily to maxima at the top of the zone. This, coupled with the occurrence of shell fragments and foraminifera, records the increasing salinity of the habitat caused by a relative rise of sea level. The fine-grained sediments indicate that quiescent conditions prevailed during their deposition.

Immediately after the time when the salinity of the habitat reached its maximum, it was abruptly lowered, never again to achieve such levels. This decline constitutes the zone boundary at 287 cm core depth. It can reasonably be inferred that the ridges of the adjacent sand deposit were constructed rapidly at this time resulting in some isolation of the lagoon and causing the decline in habitat salinity (represented by the decline in mesohalobian and euhalobian diatoms). A related distinctive feature of the Highest Zone is the minor but persistent occurrence of mesohalobes in the top 40 cm. This records a slight salinity increase which probably was brought about by the opening of the proximal inlet during the dredging of 1937-38.

In the Basin Head Harbour core, allocation of the diatoms to groups on the basis

of recognized salinity preferences permits inferences concerning changing salinity of the aquatic environment to be made. The inferred history is as follows:

The basal sediments record a ponded freshwater environment which was probably shallow. A quantity of sand was transported into the pond and consequently interrupted the normal sedimentation of fine materials. Following this deposition of sand, normal (quiet) conditions returned for a very short time, during which freshwater (Oligohalobian) diatoms, considered to be true environmental indicators, achieved a maximum frequency for all the counted sample populations. This freshwater maximum was immediately followed by the onset of marine conditions which progressively increased to a maximum at 287 cm. This maximum reflects open circulation of seawater in a coastal regime which was later terminated abruptly by the construction of a barrier. The ponding of freshwater behind the barrier is associated with limited circulation. The supposed contemporary marine transgression is recorded in a slight rise in salinity of the environment. Dredging in cultural time, and the creation of a proximal inlet is recorded with fidelity in the small but sharp increase in diatoms that prefer saline water.

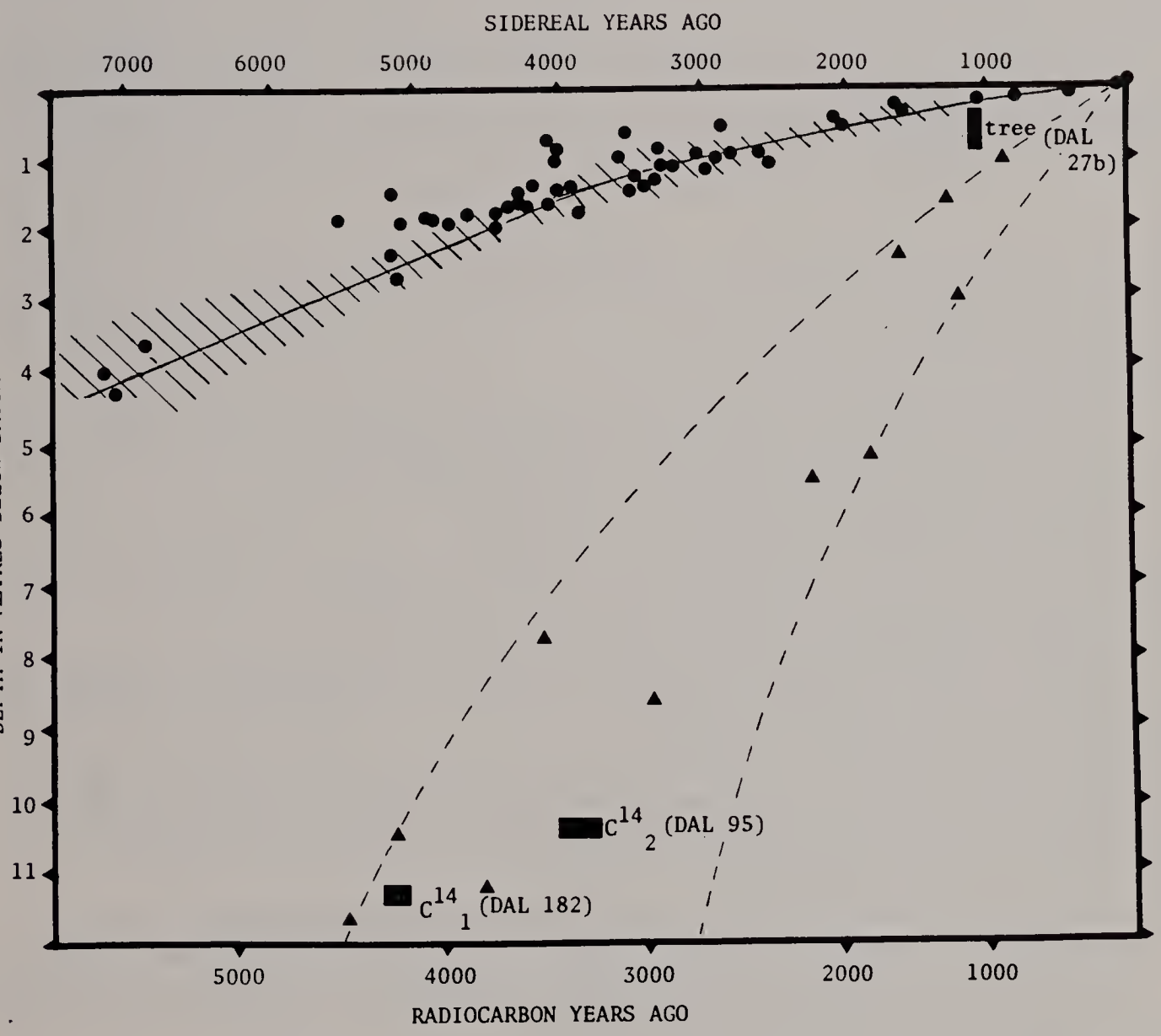
It is possible to relate the local evidence of the rise of sea level to the regional trends and to the absolute rise in sea level. Grant (1970) showed that the Maritimes are characterized by an anomolous submergence rate, relative to coastal reference areas where the record of the postglacial absolute rise of sea level is believed to be accurate.

Local data from Basin Head can be compared with the general Maritimes submergence data and information on the world-wide sea level rise (Fig 7). There is a strong similarity between the general Maritimes submergence rate and that of Basin Head. Both are clearly much more rapid than the world-wide rise of sea level for reasons discussed by Bloom (1967), Grant (1970), and Walcott (1970).

Conclusions

1. The salt marsh contains evidence of a recent rise in relative sea level. The crown of a submerged tree stump in the salt marsh lies between 41 cm and 98 cm below datum. The tree lived in this location but not while submerged by salt water. Two possible inferences can be drawn from this observation: a) the tree was drowned by the rise of sea water, or b) the tree was not killed by salt water, but died of other causes and was submerged later.

   Considering the range in errors of the known elevation and age of the tree, (1050 $\pm$ 90 radiocarbon yr, Dal 27b) it is reasonable to assume that datum one millenium ago was about equivalent to the crown elevation (or slightly lower), and thus that the death of the tree and the local datum elevation were time-equivalent. Using this information, it is possible to calculate that the post-drowning rise of relative sea level in this area is between about 3.6 and 10.2 cm/-century.
2. The data from Basin Head indicate rapid postglacial submergence and corroborate Grant's (1970) observations of high submergence rates in the Maritimes.
3. Finally, this study has demonstrated the value of diatoms as a tool and it is believed that this is the first time that diatom stratigraphy has been used in the Maritimes to develop paleoenvironmental interpretations in an attempt to solve a coastal geology problem. This comes fully 3 decades after a precedent was set by similar work in Scandinavia.



● Data from Florida (Scholl et al. 1969)

▲ Selected (extreme) data from Maritimes (Grant 1970)

■ Data from Basin Head, Prince Edward Island

Fig 7. Depth-time graph illustrating submergence of features originally formed at or above sea level; full line shows curve for Florida derived by Scholl et al. *(1969) and the dashed lines indicate limiting values for the Maritimes according to Grant (1970).*

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References

Bloom, A.L. 1967. Pleistocene shorelines, a new test of isostacy. *Geol. Soc. Am. Bull.* 78: 1477-1494.

Cleve-Euler, A. 1951-1955. Die Diatomeen von Schweden und Finnland. Vol. I(1): 1-163 (1951); Vol. 2(4): 1-158; 9); Vol. 3(4): 1-255 (1953); Vol. 4(5): 1-232 (1955); Vol 5(3): 1-153 (1952). *K. Svenska Vetenskakad. Handl.*, Ser. 4.

Crowl, G.H. 1969. Geology of Mount Stewart-Souris Map-Area, Prince Edward Island (11L/7, L/8). *Geol. Survey Can. Pap.* 67-66, 26 p.

Foged, N. 1970. The Diatomaceous flora in a postglacial Kieselguhr Deposit in southwestern Norway. *Nova Hedwigia,* 31: 169-202.

Frenguelli, J. 1938-1943. Contribucion al concimiento de las diatomeas. 1: 251-337 (1938); 2: 201-226 (1939); 3: 213-334 (1941); 4: 73-219 (1942); 5: 221-265 (1943). *Revista Mus. La Plata, Sec. Bot.*

Galehouse, J.S. 1971. Point counting. In: *Procedures in Sedimentary Petrology,* (ed. R.E. Carver). Wiley Interscience, John Wiley and Sons Inc., N.Y. pp. 385-407.

Grant, D.R. 1970. Recent Coastal Submergence in the Maritime Provinces, Canada. *Can. J. Earth Sci.* 7: 676-689.

Grant, D.R. 1972. Maritimes Sea Level Changes and Glacial Events. In: *Guidebook, Quaternary Geology Geomorphology, and Hydrogeology of the Atlantic Provinces, Field Excursion A61-C61.* (ed. D.J. Glass). XXIV International Geological Congress, Montreal, Quebec, pp. 10-23.

Grant, D.R. 1975. Recent coastal submergence of the Maritime Provinces. In: *Environmental Change in the Maritimes.* (ed. J.G. Ogden III and M.J. Harvey). Nova Scotian Institute of Science, Halifax. pp. 83-102.

Hecky, R.E., and Kilham, P. 1973. Diatoms in alkaline, saline lakes: ecology and geochemcial implications. *Limnol. Oceanogr.* 18: 53-71

Hendy, N.I. 1964. *An Introductory Account of the Smaller Algae of British Coastal Waters.* Part V. *Bacillariophyceae (Diatoms).* Fisheries Investigations Series IV, Ministry of Agriculture, Fisheries and Food, London.

Hustedt, F. 1930-1966. *Die Kieselalgen Deutschlands, Osterreichs, und der Schweiz.* Part 1, 920 p. (1930); Part 2, 845 p. (1959); Part 3, 816 p. (1961-66). In: L. Rabenhorst's *Kryptogamen-Flora,* Vol. 7. (Johnson Reprint Corporation, N.Y., 1971).

Kranck, K. 1972. Geomorphological development and post-Pleistocene sea level changes of Northumberland Strait, Maritime Provinces. *Can. J. Earth Sci.* 9: 835-844.

Ogden, J.G. and Hart, W. 1976. Dalhousie University natural radiocarbon measurements I. *Radiocarbon* 18: 43-49.

Patrick, R. and Reimer, C. 1966. *The Diatoms of the United States.* Mon. 13. Academy of Natural Sciences. Philadelphia.

Prest, V.K. 1973. Surficial deposits of Prince Edward Island. *Geol. Survey Can. Map* 1366 A.

School, D.W., Craighead, F.C. Sr., and **Stuiver, M.** 1969. Florida submergence curve revised: its relation to coastal sedimentation rates. *Science* 163: 562-564.

Setty, M.G.A.P. 1966. Preparation and method of study of fossil diatoms. *Micropaleontology* 12: 511—515.

Smith, H.L. 1873. Preparation of diatoms. In: Van Heurck, H. 1896. pp. 67-71. *A Treatise on the Diatomaceae,* translated by W.E. Baxter. Wheldon and Wesley Ltd., Codicote, Herts 1962.

VanLandingham, S.L. 1967. Paleoecology and microfloristics of Miocene diatomites. *Nova Hedwigia,* 26: 1-77.

VanLandingham, S.L. 1970. Origin of an early non-marine diatomaceous deposit in Broadwater County, Montana, U.S.A. *Nova Hedwigia,* 31: 449-484.

Walcott, R.I. 1970. Isostatic response to loading of the crust in Canada. *Can. J. Earth Sci.* 7: 716-727.

Wightman, D. and **Cooke, H.B.S.** 1978. Postglacial Emergence in Atlantic Canada. Geosci. Canada, 5: 61-65.

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Volume 28, pp. 217-230

BREEDING AND BIONOMICS OF *IDOTEA BALTICA* (PALLAS) (CRUSTACEA: ISOPODA)

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Breeding and bionomics of the valviferous isopod *Idotea baltica* were examined in 1977. This species is intertidal, an inhabitant of *Ascophyllum nodosum* and resides in this seaweed most of the year, but moves offshore to overwinter in deeper water. Adults breed only once, with peak reproductive activity between June and August. Embryonic development takes about 1.5 mo., with fecundity not strongly correlated with female body length. Extensive seasonal variations in abundance and biomass occurred which were in part related to the reproductive cycle.

Introduction

Idotea baltica (Pallas) is a member of a widely distributed genus of benthic littoral and sublittoral isopods commonly occurring on macroscopic algae, floating debris, and under rubble (Naylor 1955a, 1972). Published accounts of its ecology (Sywula 1964b), morphology and taxonomy (Naylor 1955b, Sywula 1964a), feeding (Naylor 1955c, Lukasheva 1971), and fecundity (Romanova 1974) have dealt only with populations of European coastlines, including the Baltic. Very little is apparently known about the ecology of this species in North America.

I. baltica is found intermittently in intertidal regions of the Bay of Fundy and Minas Basin, N.S., assoiiated with the alga *Ascophyllum nodosum* (L.) Le Jol., and when present usually represents a major portion of the algal epifaunal community. As a preliminary to the evaluation of an energy budget, the basic life cycle pattern had to be investigated, and collections were obtained to provide such information. This report summarizes observations on breeding and bionomics of *I. baltica* from Cape Blomidon, Minas Basin.

Materials and Methods

The intertidal population of *I. baltica* near Cape Blomidon, Minas Basin (45° 12′N, 64°20′W) was sampled from April to December of 1977 by gathering 10 to 15 kg of *A. nodosum* from the study area in plastic buckets, returning this to the laboratory, and removing the isopods by hand. A similar technique has been shown to be effective in monitoring population densities of *I. montereyensis* (Lee 1966). In addition, about 40 individuals of *I. baltica* were also collected when possible by hand picking to ensure sufficient data for fecundity measurements.

Isopods were both killed and stored at -15°C. Subsequently these animals were thawed, and length from cephalon to telson was measured to the nearest 0.1 mm with calipers. Specimens larger than 8 mm were sexed (penial papillae and rudiments of the *appendix masculinus* are discernible at this length in males), breeding condition of the female recorded, and any embryos in the brood pouch were removed, counted, and stage of embryonic development determined (see Results, for criteria). Each animal was then dried to constant weight in a vacuum oven at 70 ± 2°C and weighed to the nearest 0.01 mg on a Cahn electrobalance.

A number of embryos from different broods was measured (greatest linear dimension taken as length) with a stereomicroscope equipped with an eyepiece micrometer.

Results

Microhabit

Extensive collecting over 2 years (1976 - 1977) at Cape Blomidon indicates that *I. baltica* is associated with only one alga of the intertidal zone, *A. nodosum*. It was never found under stones and only occasionally collected from small tidal pools devoid of macroscopic seaweeds. Males were generally found in the outermost parts of an *A. nodosum* clump, whereas females, especially those with broods, tended to occupy the branches nearest the holdfast.

Not all shorelines with *A. nodosum* supported populations of *I. baltica*. Extensive sampling of selected intertidal habitats along the southern coast of the Bay of Fundy revealed only occasional specimens. The one exception was Black Rock (45°10'N, 64°48'W) where a large population inhabited *A. nodosum* on the sheltered side of a massive basalt outcrop, although it did not occur in extensive *A. nodosum* mats along the unprotected areas of the same shoreline. Thus, *I. baltica* apparently prefers intertidal habitats not exposed to wave action.

I. baltica does not inhabit the intertidal zone in winter, presumably moving offshore at low water temperature (Fig 7).

Another idoteid, *I. phosphorea* Harger was often found amongst *A. nodosum*, but never as abundantly as *I. baltica*.

Breeding Cycle

The breeding behavior of *I. baltica* was discovered to be similar to that of other species of *Idotea*. Females are held *in copula* beneath the males for 2 to 3 days prior to sperm transfer. Partial molting of the female is accompanied by fertilization; ova are thereafter extruded into the brood pouch which forms upon completion of molting. The embryo passes through 4 developmental stages, the fourth of which represents the first free living instar. These stages are separable by the following criteria:

STAGE I	Embryo spherical, yellowish, yolk centrally placed, surrounded by 2 embryonic membranes.
STAGE II	Embryo curvilinear, yolk central, segmentation complete, surrounded by 1 embryonic membrane.
STAGE III	Embryos of similar morphology to adult, abundant yolk in gut, no setae on pereiopods, not surrounded by an embryonic membrane.
STAGE IV	Synonymous with first free-living instar, no yolk in gut, setae on all appendages.

Embryos at a given developmental stage were of relatively constant length. Recently transformed Stage II embryos were smaller than their older counterparts, possibly being a function of water uptake. The mean length of each stage is included in Table 1.

I have expressed the breeding cycle in terms of degree of sexual maturity of the females and stage of embryonic development of the brood. This was necessary as very few newly released juveniles were collected by the sampling procedure I employed. Females were considered reproductively dormant if neither oöstegite

Table I. Mean length of embryonic stages of *I. baltica*

stage	mean length (μm) ± 1 s.d.	number of measurements
I	488 ± 37	20
early II	838 ± 39†	20
late II	1133 ± 55†	74
III	1731 ± 68	50
IV	1944 ± 73	21

† significantly different ($t = 27.44$, 92 d.f., $p. < 0.001$)

buds (flap-like precursors of the oöstegites) were present. Females with oöstegite buds only were considered immature, and those which had molted to acquire oöstegites (forming complete brood pouch) were therefore mature and further subdivided on the basis of stage of development of the embryos. Several females had incompletely developed brood pouches (usually only the fifth pair of oöstegite developed, the others remaining as oöstegite buds). These females have been omitted from further discussion.

The seasonal occurrence of these stages is shown in Figure 1. Females with Stage IV embryos have not been included because this stage is synonymous with the first free-living instar. Only reproductively dormant females were present in late April, but by mid-June most females brooded Stage I embryos. A period of reproductive dormancy directly followed breeding, and the last collection in November comprised many females with oöstegite buds. This suggests a winter period of reproductive activity, although it cannot be supported empirically. From Figure 1 the period of embryonic development (Stages I - III) can be estimated to be 1.5 months.

Fecundity

The correlation between the number of embryos in each brood and female body length (Fig 2) apparently could be equally well described exponentially (Daborn 1977), linearly (Jones & Naylor 1971), or logarithmically (Sheader 1977). The linear relationship, which has the highest corresponding coefficient of correlation (Table II), was accordingly chosen although it accounts for only 32.2% of the variation ($P < 0.01$) (Fig 2, inset). The linear regression equation relating fecundity (E) to body length (L) is

$$E = 12.4\,L - 35.1$$

Again, because Stage IV embryos are potentially capable of leaving the brood pouch (and hence subject to underestimation), they have been omitted. No reduction in brood size with advancing development (Stages I - III) is evident from Figure 2, suggesting little or no embryonic mortality or premature extrusion.

Sex Ratio

The sex ratio was seldom equal to unity, varying both as a function of body length and season. The seasonal sex ratio was bimodal, an early predominance of males in spring later replaced by a summer predominance of females (Fig 3). This argues for an earlier spring migration by males back to the intertidal zone, as well as death of adults of both sexes after their respective roles in the breeding cycle have been completed. On a length basis (Fig 4), females dominated the smaller length classes (< 18 mm) whereas males were more abundant at lengths > 18 mm.

Seasonal Changes in Abundance and Biomass

Because *I. baltica* has a relatively clumped distribution, monitoring abundance

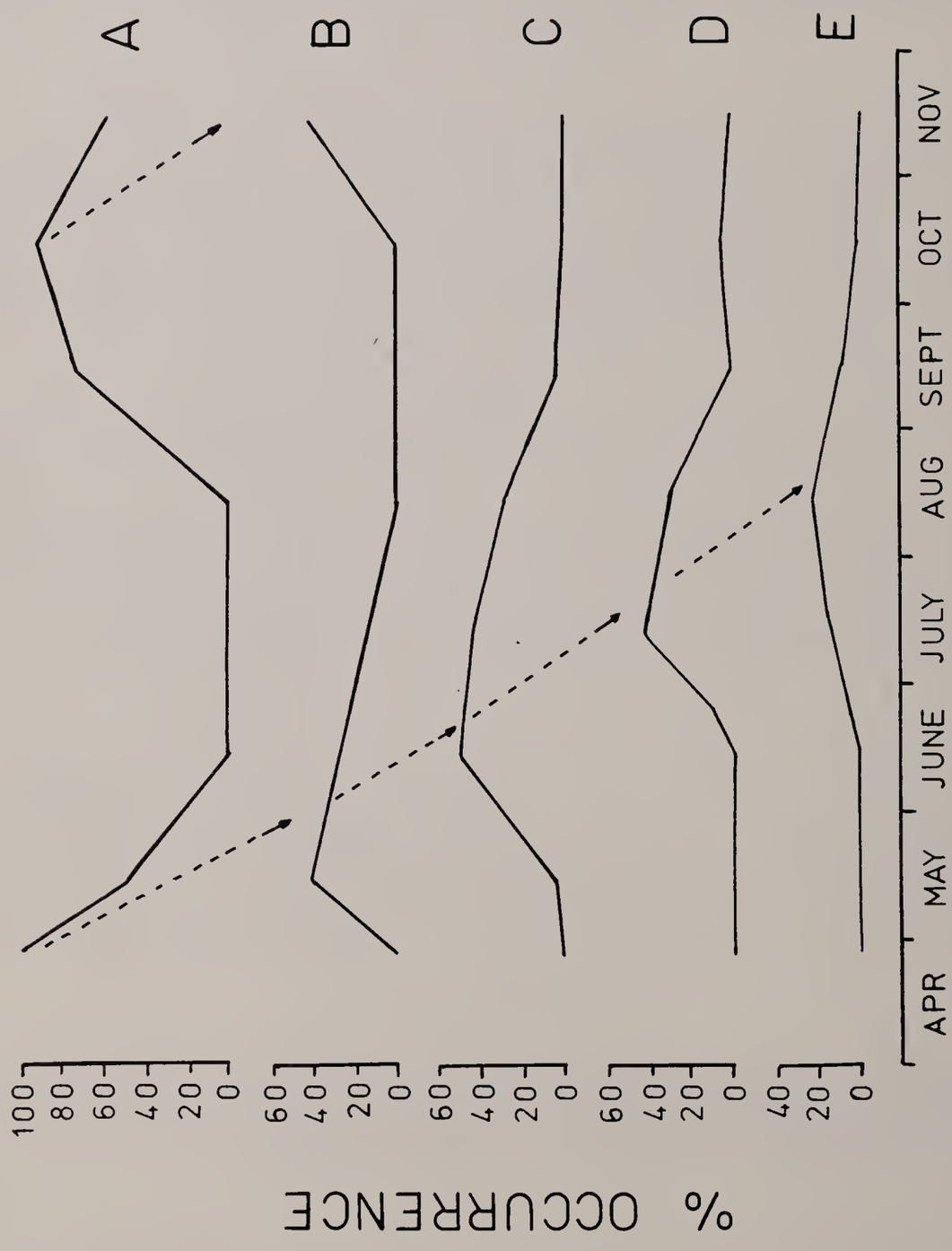

Fig 1. Seasonal occurrence of major divisions of the breeding cycle of *I. baltica*: A - reproductively dormant females; B - immature females; C - Stage I embryos; D - Stage II embryos; E - Stage III embryos (For further explanation

Table II. Correlation Coefficients (r) for different equations relating fecundity to female body length (n = 119)

type of relationship	r	% variation accounted for by relationship
logarithmic	0.564	31.8
exponential	0.555	30.8
linear	0.567	32.2

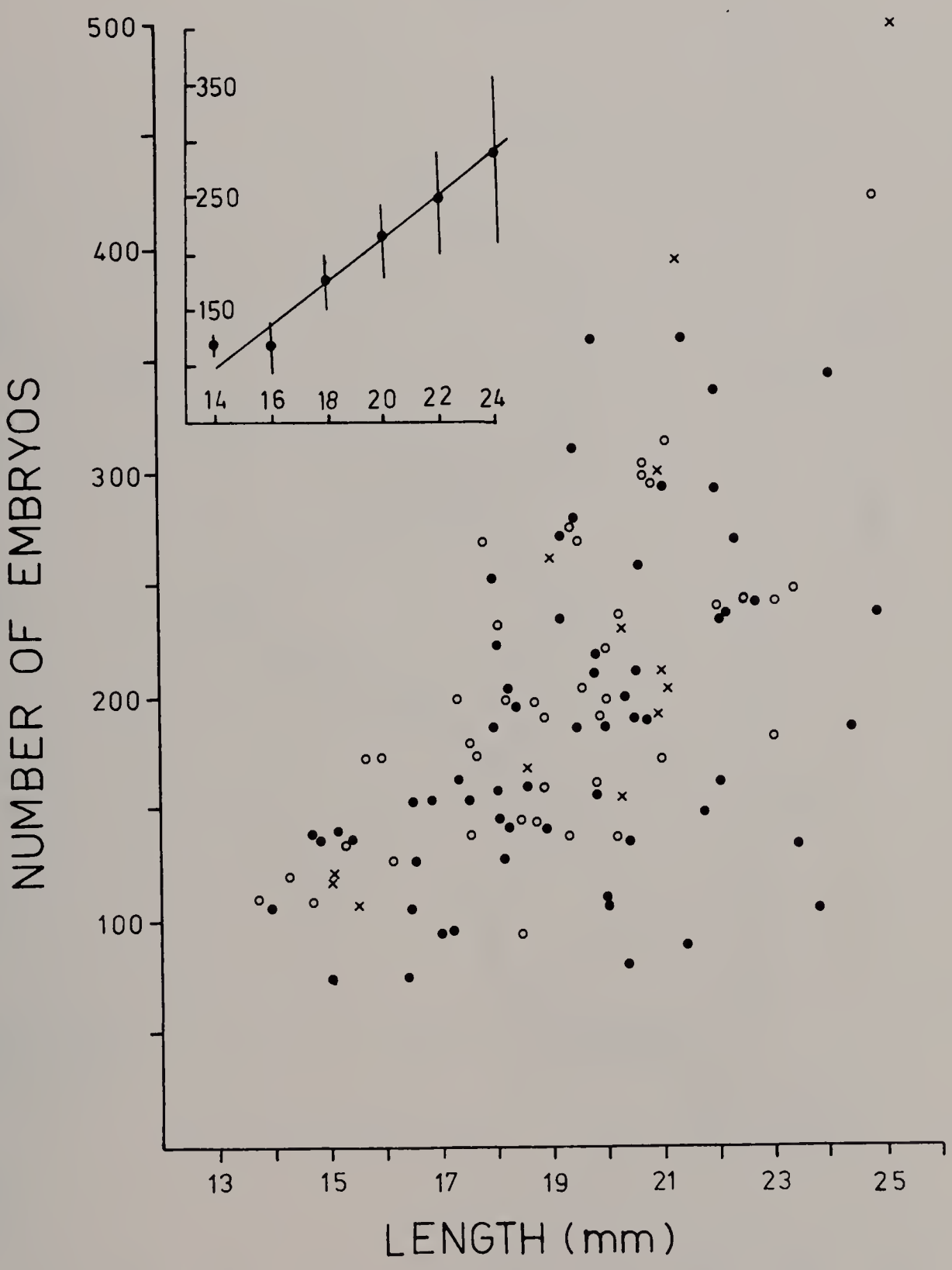

Fig. 2. *Number of embryos per female I. baltica* as a function of body length ● - Stage I; 0 - Stage II; X - Stage III; inset - mean (± 1 s.d.) number of embryos in 2 mm increment size classes (all stages of development).

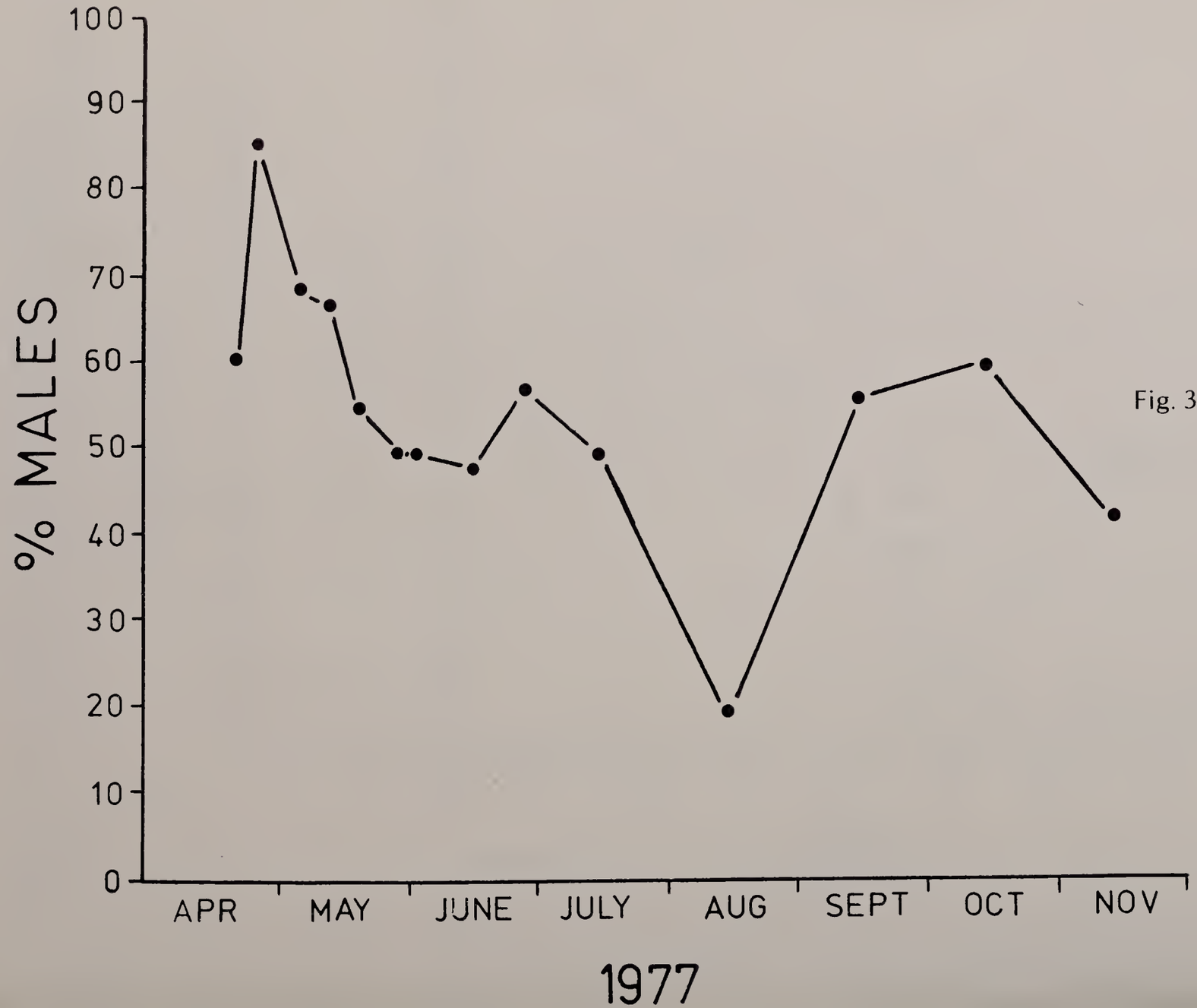

Fig. 3. Percent male *I. baltica* on each sampling date (all size ranges included).

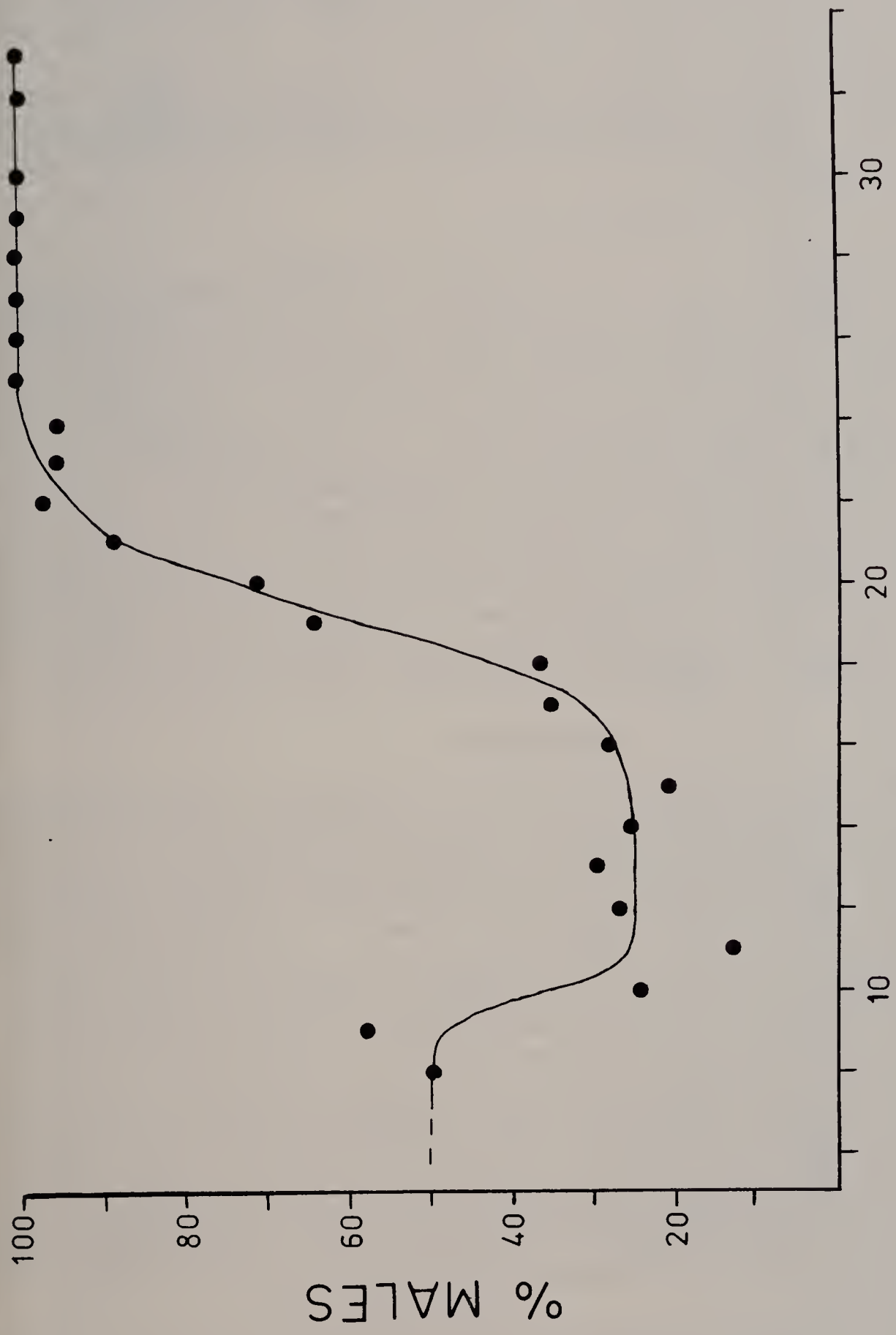

Fig 4. Percent male *I. baltica* in successive 1 mm increment size classes (all collecting dates included).

and biomass by hand collecting for a standard length of time (e.g. Jones & Naylor 1971; Naylor & Haahtela 1966; Jones 1974) was unsuitable. Instead, *A. nodosum* was collected from a broad area, pooled, and the average number and biomass of *I. baltica* calculated for 10 kg seaweed. This was not only the most reliable way to calculate these parameters, but also provided animals of a size distribution corresponding to those in the field.

The number of animals (per 10 kg *A. nodosum*) dropped steadily from 42 to <10 between mid May and mid August (Fig 5). Thereafter, as a result of recruitment, abundance increased considerably to >90 in mid November.

Biomass (mg-dry weight per 10 kg *A. nodosum*) also decreased steadily from mid May to mid June. An increase in late June was evident because of the presence of mostly large adults in the population. Thereafter, trends in biomass essentially followed those of abundance.

Population Size Structure

Because the number of isopods collected (Fig 5) was too few to divide the sample adequately into small increment size classes, the mean ($\pm$ 1 s.d.) male and female length on each date was determined instead (Fig 6). A good deal of variability exists, bu he mean lengths follow a trend that can be correlated with the breeding cycle. Mean male length decreased during May ($t=1.765$, 22 d.f., $p<0.05$), presumably resulting from death of large overwintering males. A sharp decrease in both mean length and variability occurred from June to September ($t=11.363$, 21 d.f., $p<0.001$) as large post-reproductive males disappeared. Thereafter mean male length increased slightly ($t=5.098$, 56 d.f., $p<0.001$). Mean female length was relatively constant most of the year ($p>0.05$), but a decrease during August and September occurred ($t=3.074$, 32 d.f., $p<0.005$) as a result of disappearance of larger post-reproductive females. On the basis of these observations and those concerning abundance and biomass, it is probable that individual *I. baltica* breed only once.

Discussion

Naylor (1955a) reports that *I. baltica* is chiefly a sublittoral species, occurring amongst attached and decaying algae, and suggests that wave action may be the limiting factor in the general inability of the sublittoral species of *Idotea* to colonize intertidal habitats. At Cape Blomidon, wave action is usually negligible, enabling *I. baltica* to colonize the intertidal seaweed *A. nodosum*. It is not known why this isopod is associated only with this particular alga. At Cape Blomidon other macroscopic seaweeds include *Fucus edentatus* Pyl., *Chondrus crispus* Stackh., *Gigartina stellata* (Stackh.) Batt. and *Laminaria longicruris* Pyl. The last three species may not provide a sufficiently humid atmosphere when uncovered at low tide, or perhaps do not support the proper epiphytic flora upon which *I. baltica* may feed. However, *Fucus* can almost certainly provide a humid microhabitat, but has been shown to produce phenolic compounds inimical to other organisms (e.g. Sieburth 1969). The color polymorphism of this species has been well documented (Matzdorff 1883; Pieron 1913; 1914; Peabody 1939; Suneson 1947), and it suffices here to mention that *I. baltica* at Cape Blomidon are mainly green (never red) and appear extremely well color matched to *A. nodosum*. Whether this is a cause or an effect is not known at this time.

One problem encountered during this study was difficulty in collecting juveniles (<8 mm). Breeding presumably occurred, as females with advanced (Stage III-IV) embryos in their brood pouches were common. This indicates that adult and juvenile *I. baltica* do not occupy the same microhabitat. Sywula (1964b) demonstrated that juveniles display a strong positive phototaxis during the first 24 hr. following release from the brood pouch, causing them to swim at or near the surface. As a result, they might be deposited on the mud surface as the tide ebbs,

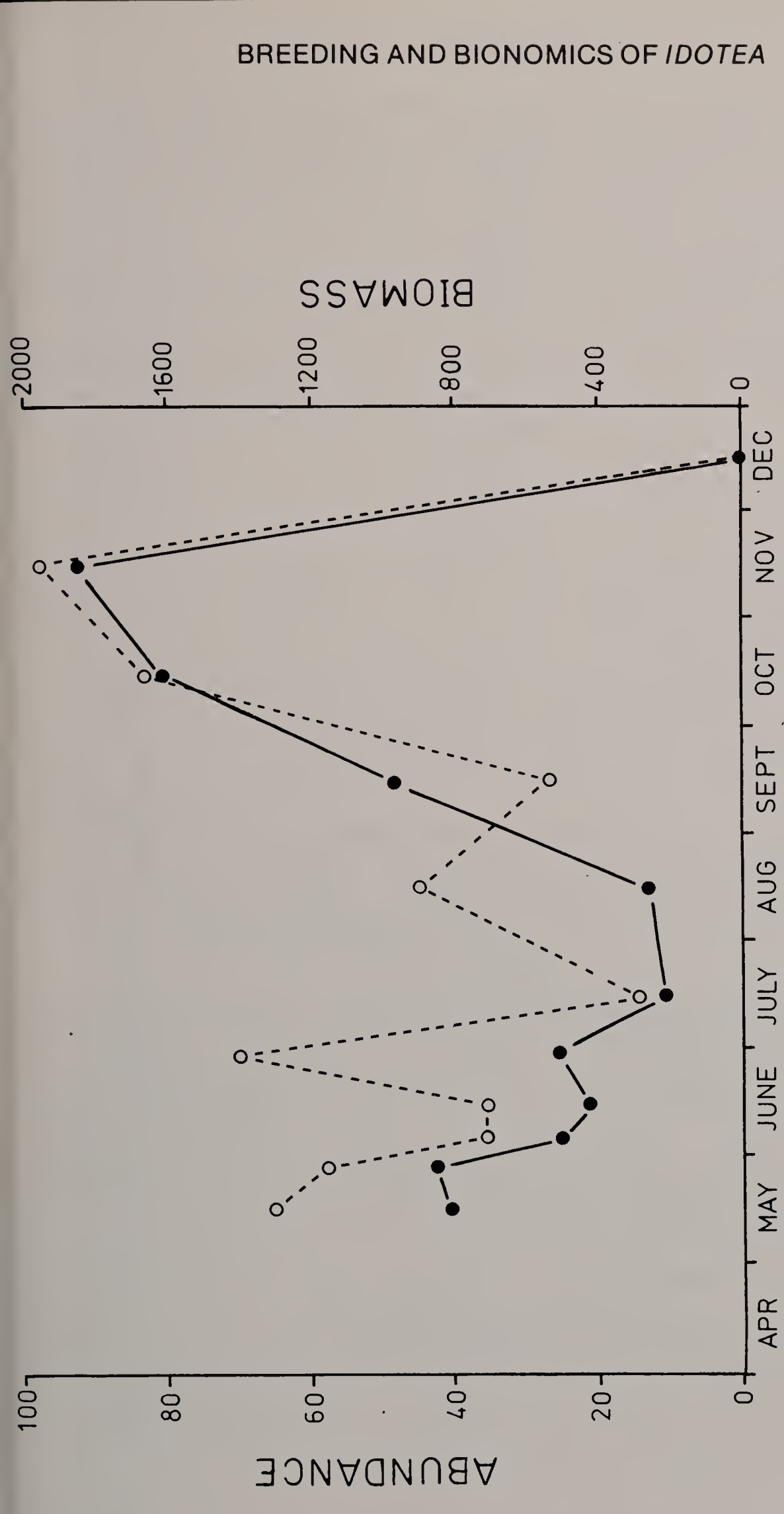

Fig. 5. Abundance (●—●-as number of animals per 10 kg of *A. nodosum*) and biomass (0—0-as mg-dry wt per 10 kg of *A. nodosum*) of *I. baltica* on each collecting date.

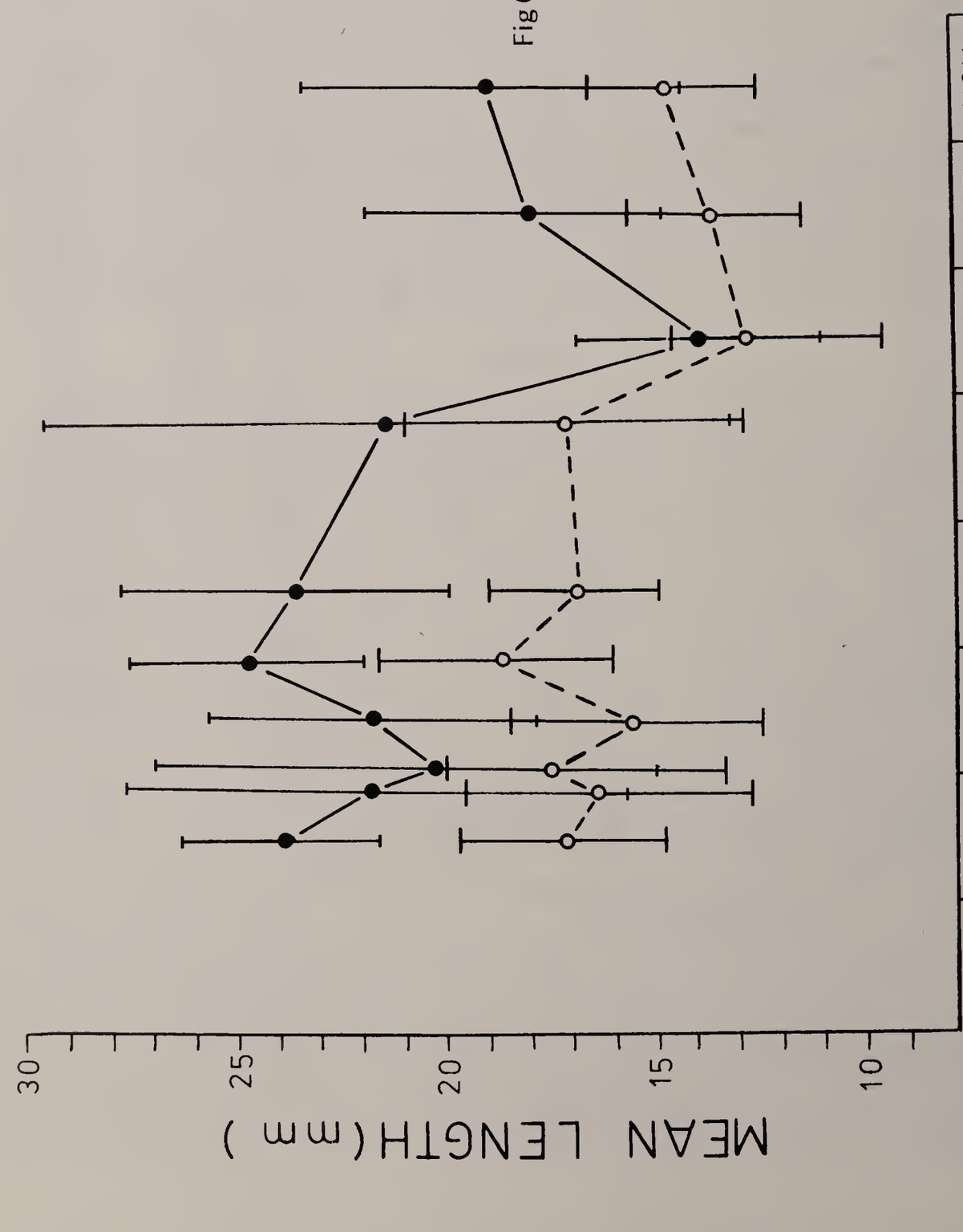

Fig 6. Mean length (± 1 s.d.) of male (•) and female (°) *I. baltica* on each collecting date.

particularly where the tidal amplitude is large (16 m in the Minas Basin (Bousfield & Leim 1959)). Here the juveniles could remain, feeding upon epipelic diatoms and detritus, until they are large enough to grasp the thalli of *A. nodosum*. This, if true, would allow the young to utilize a resource not available to the larger adults. It is certain that the intertidal mud flats support a flora and fauna sufficient to maintain young *I. baltica,* as other deposit feeders including *Chiridotea caeca* (Say), *Corophium volutator* (Pallas) and numerous polychaetes are abundant in the area.

The estimated period of embryonic development (1.5 mo) is slightly longer than that reported for some other members of the genus (Kjennerud 1950; Sheader 1977). Water temperature, which likely influences the duration of embryonic development (Steele & Steele 1973), was lowest during Stage I of embryonic growth (Fig 7) and might explain its extended peak of occurrence (cf Fig 1).

Fecundity was only weakly correlated with female body length, reflecting a good deal of inherent variability not uncommon among crustaceans (Daborn 1976, 1977; Hopkins 1977). This variability, which increased as body length increased, indicates that the trade-off between growth and reproduction is not constant for each member of a given population. Sheader (1977) discovered that infestation by a cryptoniscid parasite resulted in lowered numbers of Stage I embryos, particularly in larger females, but no brood pouch parasites were observed in this study.

As is general for isopods, all the embryos in a single brood were at the same stage of development. No reduction in brood size between Stage I-III was apparent, presumably because the brood pouch enlarges sufficiently in volume to permit the increase in size of the embryos. An exceptional species, *I. viridis,* broods embryos at different stages of development and undergoes brood reduction often exceeding 75% (Howes 1939).

Apparently no generalizations can be made concerning the number of broods produced by female species of *Idotea*. *Idotea emarginata* (Naylor 1955d), *I. viridis* (Howes 1939) and possibly *I. pelagica* (Sheader 1977) may produce two broods, whereas *I. neglecta* (Kjennerud 1950) and *I. baltica* (this study) produce only one. In addition, *I. baltica* apparently has the greatest fecundity of any species of *Idotea;* the maximum brood size encountered in this study was 567 embryos. Other species have relatively smaller broods (Kjennerud 1950; Howes 1939). Our laboratory recently demonstrated by the use of calorimetry that large quantities of high energy compounds (lipids) are mobilized in the formation of gametes, especially ova (Strong & Daborn, 1978) suggesting that *I. baltica* may invest suicidally in reproduction.

The length-specific sex ratio deserves some mention. Through a combination of determining the number of segments on the flagellum of the second antenna, application of the law of geometrical progression and inference from the literature (e.g. Howes 1939), I assumed that male *I. baltica* molt once or twice more often than females during the life cycle, in addition to growing to a larger length. But males and females become sexually mature at the same time of year. This means that females have a longer intermolt period than males. As a consequence, females numerically 'fill up' the smaller length classes, resulting in a sex ratio strongly in favor of females between 8 mm (acquisition of sexual characteristics) and 18 mm. At lengths greater than 18 mm, females are less common and after 25 mm only males are present. Wenner (1972), in an extensive compilation of the influence of size on crustacean sex ratios, has shown that differential molting frequencies and growth rates can often account for unequal sex ratios of the type demonstrated by *I. baltica*.

Trends in abundance and biomass were similar to those expected for a semelparous population with one truncated breeding period. Kjennerud (1950), studying the ecology of *I. neglecta,* noted similar changes in abundance, including a winter paucity of animals. Steele (1975) found much the same pattern of seasonal occurrence in *Gammarus oceanicus* Sergerstråle on Newfoundland shores. At Cape

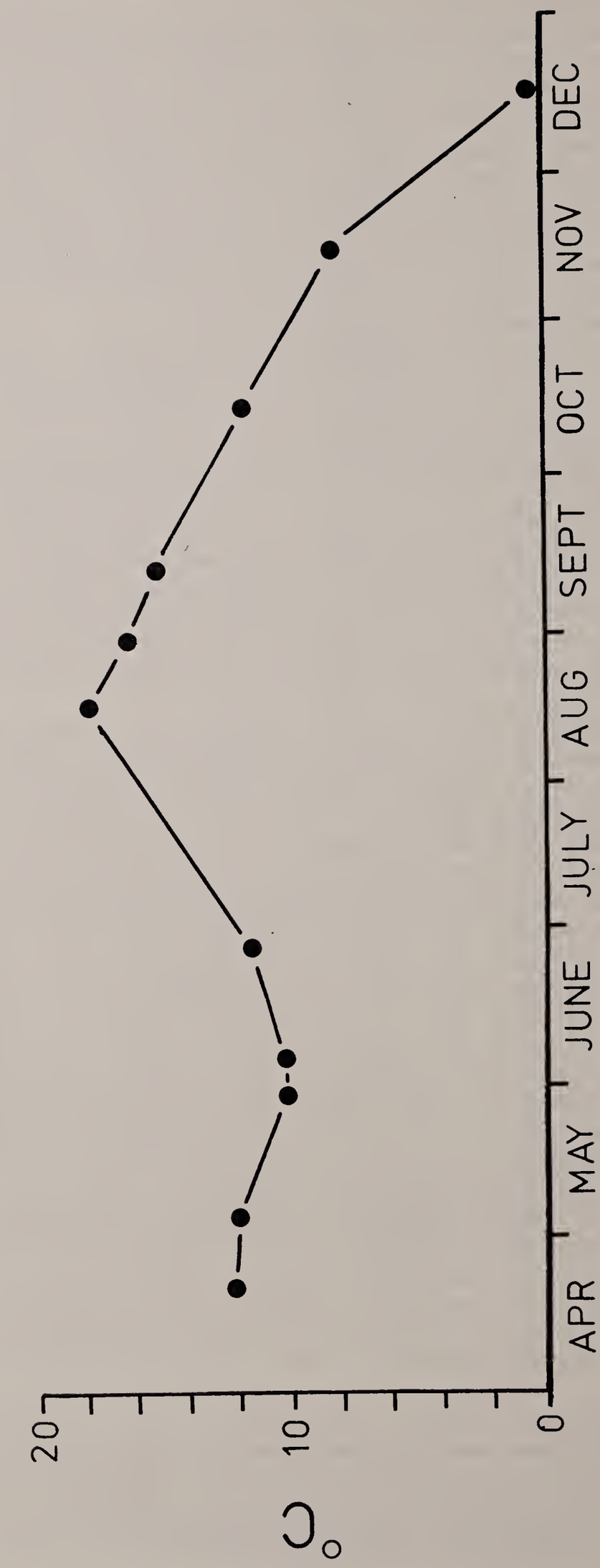

Fig 7. Water temperature at Cape Blomidon on each collecting date.

Blomidon, movement off-shore into deeper water to overwinter is essential, as extreme tidal amplitude (16 m) and extended exposure accompanied by sub-freezing temperatures could result in high mortality (Bleakney 1972).

This migration may be passive rather than active. Horlyck (1973) showed by using photocells that *I. baltica* from Denmark is inactive from November to February; during this period daylight averaged 9.2 to 10.7 $hr \cdot d^{-1}$. This photoperiod is similiar to that during Nova Scotia winters. Marsden (1976) demonstrated that the saltmarsh isopod, *Sphaeroma rugicauda* (Leach) becomes inactive below 4°C, and consequently tends to be washed out into deeper water. These observations suggest that when the water temperatures drops to a certain point, *I. baltica* is washed into deeper water, and if the photoperiod suppresses activity may not be able to move back inshore should the water temporarily warm up. This would explain the absence of even a single specimen in the *A. nodosum* in winter.

Acknowledgements

It is a pleasure to acknowledge Dr. Graham Daborn for financial support (NRC Grant No. A9697) and constructive criticism throughout this and other endeavors. I also thank Dr. Sherman Bleakney and Mr. Sherman Boates for criticism of the manuscript, Dr. Peter C. Smith for valuable comments on sampling procedure, and Ms. Cathy Pennachetti and Ms. Michelle Roberge for collection of the August samples.

References

Bleakney, J.S. 1972. Ecological implications of annual variation in tidal extremes. *Ecology* 53: 933-938.

Bousfield, E.L. and **Leim, A.H.** 1959. The fauna of the Minas Basin and Minas Channel. *Nat. Mus. Can. Bull.* 166: 30 pp.

Daborn, G.R. 1976. The life cycle of *Eubranchipus bundyi* (Forbes) (Crustacea: Anostraca) in a temporary vernal pond of Alberta. *Can. J. Zool.* 54: 193-201.

Daborn, G.R. 1977. The life history of *Branchinecta mackini* Dexter (Crustacea: Anostraca) in an argillotrophic lake of Alberta. *Can. J. Zool. 55: 161-168.*

Horlyck, V. 1973. Seasonal and diel variation in the rhythmicity of *Idotea baltica* (Pallas) and *Idotea granulosa* Rathke. *Ophelia* 12: 117-127.

Hopkins, C.C.E. 1977. The relationship between maternal body size and clutch size, developmental time and egg mortality in *Euchaeta norvegica* (Copepoda: Cananoida) from Loch Etive, Scotland. *J. Mar. Biol. Ass. U.K.* 57: 723-733.

Howes, N.H. 1939. Observations on the biology and post-embryonic development of *Idotea viridis* (Slabber) (Isopoda: Valvifera) from New England Creek, Southeast Essex. *J. Mar. Biol. Ass. U.K.* 23: 279-310.

Jones, M.B. 1974. Breeding biology and seasonal population changes of *Jaera nordmanni nordica* Lemercier (Isopoda: Asellota). *J. Mar. Biol. Ass. U.K.* 54: 727-736.

Jones, M.B. and **Naylor, E.** 1971. Breeding and bionomics of the British members of the *Jaera albifrons* group of species (Isopoda: Asellota). *J. Zool.* (Lond.) 165: 183-199.

Kjennerud, J. 1950. Ecological observations of *Idotea neglecta* G.O. Sars. *Bergen Arb. Naturv. R.* 7: 5-47.

Lee, W.L. 1966. Color change and the ecology of the marine isopod *Idothea (Pentidotea) montereyensis* Maloney, 1933. *Ecology* 47: 930-941.

Lukasheva, T.A. 1971. Quantity of food consumed as a function of body weight in *Idotea baltica* (Pallas). *Hydrobiol. J.* 7: 87-90.

Marsden, I.D. 1976. Effect of temperature on the microdistribution of the isopod *Sphaeroma rugicauda* from a saltmarsh habitat. *Mar. Biol.* 38: 117-128.

Marzdorff, C. 1883. Ueber die Färbung von *Idotea triscupidata* Desm. *Jenaische Zeit Naturwiss.* 16: 1-58.

Naylor, E. 1955a. The ecological distribution of British species of *Idotea* (Isopoda). *J. Anim. Ecol.* 24: 255-269.

Naylor, E. 1955b. The comparative external morphology and revised taxonomy of the British species of *Idotea*. *J. Mar. Biol. Ass. U.K.* 24: 467-493.

Naylor, E. 1955c. The diet and feeding mechanism of *Idotea*. *J. Mar. Biol. Ass. U.K.* 24: 347-355.

Naylor, E. 1955d. The life cycle of the isopod *Idotea emarginata* (Fabricius). *J. Anim. Ecol. 24: 270-281.*

Naylor, E. 1972. *British Marine Isopods.* Academic Press, London.

Naylor, E. and **Haahtela, I.** 1966. Habitat preferences and interspersion of species within the superspecies *Jaera albifrons* Leach (Crustacea:Isopoda). *J. Anim. Ecol.* 35: 209-216.

Peabody, E.B. 1939. Pigmentary responses in the isopod *Idothea*. *J. Exp. Zool.* 82: 47-83.

Pieron, H. 1913. Le mécanisme de l'adaptation chromatique et la livrée nocturne de l' *Idotea tricuspidata* Desm. *C.R. Acad. Sci.* 157: 951-953.

Pieron, H. 1914. Recherches sur la comportement chromatique des invertébres et en particulier des isopodes. *Bull. Sci. France Belg.* 48: 30-79.

Romanova, Z.A. 1974. Length-weight ratios and fecundity in *Idotea baltica baltica* (Pallas) from the Baltic Sea. *Hydrobiol. J.* 10: 55-59.

Sheader, M. 1977. The breeding biology of *Idotea pelagica* (Isopoda: Valvifera) with notes on the occurrence and biology of its parasite *Clypeoniscus hanseni* (Isopoda: Epicaridea). *J. Mar. Biol. Ass. U.K.* 57: 659-674.

Sieburth, J. 1969. Studies on algal substances in the sea. III. The production of extracellular organic matter by littoral marine algae. *J. Exp. Mar. Biol. Ecol.* 3: 290-309.

Steele, D.H. 1975. Seasonal changes in abundance of *Gammarus oceanicus* (Crustacea: Amphipoda) in Newfoundland. *Can. J. Zool.* 54: 2019-2022.

Steele, D.H. and **Steele, V.J.** 1973. The biology of *Gammarus* (Crustacea: Amphipoda) in the northwestern Atlantic. VII. The duration of embryonic development in five species at various temperatures. *Can. J. Zool.* 51: 995-999.

Strong, K.W. and **Daborn, G.R.** 1978. Seasonal variations in ash and calontic content of *Idotea baltica* (Pallas) (Crustacea: Isopoda).*Can. J. Zool.* 56 (in press).

Suneson, S. 1947. Color change and chromatophore activators in *Idothea*. *K. Fysiografiska Sällskapets I Lund Handlingar N.F.* 58: 2-34.

Sywula, T. 1964a. A study on the taxonomy, ecology and the geographical distribution of species of the genus *Idotea* Fabricius (Isopoda, Crustacea) in Polish Baltic. I. Taxonomical part. *Bull. Soc. Sci. Lett. Poznan* 4D: 141-172.

Sywula, T. 1964b. A study on the taxonomy, ecology, and geographical distribution of species of the genus *Idotea* Fabricius (Isopoda, Crustacea) in Polish Baltic. I. Ecological and Zoogeographical part. *Bull. Soc. Sci. Lett. Poznan 4D: 173-200.*

Wenner, A.M. 1972. Sex ratio as a function of size in marine Crustacea. *Am. Nat. 106: 321-350.*

PROCEEDINGS OF MEETINGS

1977-1978

HALIFAX CHAPTER

1st Ordinary Meeting, 12th October 1977 (jointly with the Valley Chapter, Dalhousie University)

(2nd A.C. Neish Memorial Lecture) "Science and social concern, a case history in plant physiology", A.W. Galston, Yale University.

2nd Ordinary Meeting, 7th November 1977

"Bill C-26 and federal support of research in Canada", B.A. Gingras, National Research Council of Canada.

3rd Ordinary Meeting, 5th December 1977

"Nitrogen fixation: Implications for the food supply", D. Patriquin, Dalhousie University.

4th Ordinary Meeting, 9th January 1978

"The Arctic environment and exploitation of resources", J. Allen and S. Conover, MacLaren Atlantic Ltd.

5th Ordinary Meeting, 6th February 1978

"Factors affecting infectivity of viruses", K.R. Rozee, Dalhousie University.

6th Ordinary Meeting, 6th March 1978

"Research on fusion as a source of energy", M.P. Bachinsky, M.P.B. Technology Inc.

Extraordinary Meeting, 3rd April 1978

"Tree power and biomass energy", R. Overend, Department of Energy, Mines, and Resources.

7th Ordinary Meeting, 10th April 1978 (jointly with the Valley Chapter, Acadia University)

"Breeding rhododendrons and azaleas", D.C. Craig, Kentville Experimental Station.

VALLEY CHAPTER

1st Ordinary Meeting, 12th October 1977 (jointly with the Halifax Chapter, Dalhousie University)

"Science and social concern, a case history in plant physiology", A.W. Galston, Yale University.

2nd Ordinary Meeting, 14th November 1977

"Castle Frederick Observatory - first in the western hemisphere?", R. Bishop, Acadia University.

3rd Ordinary Meeting, 12th December 1977

"Here's solar heating", W. Naugler, Acadia University.

4th Ordinary Meeting, 9th January 1978

cancelled

5th Ordinary Meeting, 13th February 1978

"Ecological study of the Minas Basin and Scotts Bay - two contrasting environments", J. Trevors, Acadia University.

6th Ordinary Meeting, 13th March 1978

"Asbestosis", J.J. Quinlan, Miller Hospital.

7th Ordinary Meeting, 10th April 1978 (jointly with the Halifax Chapter, Acadia University)

"Breeding rhododendrons and azaleas", D.D. Craig, Kentville Experimental Station.

THE PRESIDENT'S REPORT

During 1977-78 the Institute held two successful lecture series, one in Halifax and one in the Annapolis Valley. The series in Halifax was arranged by R.J. Conover, P.H. Odense, and F.J. Simpson and that in the Annapolis Valley by T.C. Haliburton, F.C. Bent, and R. Olsen. The arrangements were completed during the summer of 1977 so that for the first time it was possible to distribute in September, the lecture program for the 1977-78 season. This was a factor in rekindling an interest in the Institute with a consistent attendance at the lectures. During the 1977-78 season, most of the lectures were held in the auditorium of the Nova Scotia Museum, whose hospitality is greatly appreciated. We are similarly indebted to Dalhousie University and to the Nova Scotia Technical College for the facilities they have made available over the years.

The Institute, in co-operation with the A.C. Neish Memorial Trust, Dalhousie University, and the Atlantic Regional Laboratory, once again participated in sponsoring the A.C. Neish Memorial Lecture. The Institute hosted a prelecture dinner with Mrs. A.C. Neish and members of the family as guests. The lecture, given by Dr. Galston of Yale University as part of the celebrations of the 25th Anniversary of the Atlantic Regional Laboratory, appears in Volume 28 of the PROCEEDINGS along with the other lectures presented during the celebrations.

Council appointed D.S. Davis, K. Hellenbrand, and I.A. McLaren as a committee on Membership. A booth providing information about the Institute was set up at the A.C. Neish Memorial Lecture and a copy of the Institute's lecture program together with an application form was mailed to all scientists on the staff of the Nova Scotia Technical College, Dalhousie, St. Mary's, and Mount St. Vincent Universities. Twenty-nine new members were obtained. There are 125 ordinary members of the Halifax and 31 members of the Valley Chapter who have paid dues, 22 who have purchased life memberships, 18 who are one year, 17 two years, and 10 three or more years in arrears. The latter will be dropped from the roles. Seventeen institutions have paid fees and 10 are in arrears.

Because of fiscal constraints, the Institute was not able to complete publication of Volume 27 of the PROCEEDINGS during 1974-75. J. McLachlan was appointed editor in 1976 and with the assistance of the able Editorial Board (H.B.S. Cooke, I.A. McLaren, P.J. Wangersky, and S.P. vander Kloet) was successful in overcoming a number of obstacles. The Province of Nova Scotia gave the Institute grants of $500 in 1977 and 1978 to support publication of the PROCEEDINGS. With the objective of reinstituting regular publication, the Editor and Treasurer prepared a submission to the National Research Council for a grant. The application was successful and a grant of $2,500 was received. The immediate financial problems have been resolved. However, the Institute needs to take measures to ensure continued publication of the PROCEEDINGS, the preparation and publication of a cumulative index, and the periodic publication of monographs or reviews. As a first step, the Editorial Board has established a voluntary page charge. Now that regular publication of the PROCEEDINGS has been reestablished, the editor would be pleased to receive manuscripts for possible publication.

In 1976, President W.D. Jamieson appointed H.A. Ellenberger, T.C. Haliburton, and F.J. Simpson as a committee of three to review and report on the relationships between the Council and Chapters. The report was submitted to Council in the spring of 1977. The committee recommended that the by-laws of the Institute be revised so as to establish representation of Chapters on Council and a more formal relationship between the parent organization and the Chapters. Council was of the opinion that the Institute should actively encourage the establishment of additional Chapters in other regions of Nova Scotia or the Atlantic Region. Accordingly, Council undertook to revise the by-laws of the Institute with the objectives of pro-

viding for the establishment and representation of Chapters on Council, and of providing for the establishment of separate investment, operating and publication accounts in order to qualify for grants and solicitations of donations as a charitable foundation. The proposed changes in the by-laws were accepted by the membership and adopted at the annual meeting.

During the year the members of the Institute were saddened by the death of colleagues who had been active members of the Institute. Among these were Mr. John Longard who worked at the Defence Research Establishment before his retirement, Dr. Keith Stewart, a well known chemist at the Experimental Farm at Kentville, and Dr. Tikvah Edelstein, an internationally known phycologist at the Atlantic Regional Laboratory, Halifax.

I am confident that the measures taken this year will result in an improved financial position and will provide the incoming Executive and Council with a firmer base on which to build. I wish to thank the officers of the Institute, the members of Council, the Editor and members of the Editorial Board for the support they have given me and the large amount of work done on behalf of the Institute. My reports and the revisions to the by-laws would not have been possible without the assistance of Mrs. L. Cameron and the secretarial staff at ARL, to whom I express my appreciation and thanks.

F.J. Simpson

INSTRUCTIONS TO AUTHORS

The *Proceedings of the Nova Scotian Institute of Science* publishes the proceedings of the Institute and original articles, including notes, pertaining to the natural sciences of the Atlantic Provinces, especially in biology and geology. Manuscripts may be either in English or French, and acceptance for publication is based on recommendations of referees.
Manuscripts should be typewritten, double-spaced on white paper 21.5 by 28 cm (8.5 by 11 in) with margins of 4 cm (1.5 in). Underline only material to be set in italics, and use capital letters only when letter or words should appear in capitals in the printed paper. Layout and style should follow that used in this volume. The original copy and one duplicate are required. Each page of the manuscript should be numbered, the first page carrying only the title, authors' names and affiliations, and any necessary footnotes.

Spelling should follow that of **Webster's Third New International Dictionary**, and authors are responsible for consistency in spelling.

Abbreviations, nomenclature, and symbols for units of measurements should follow international recommendations. Metric units, SI units and decimals should be used whenever possible. Use day/month/year sequence for dates. Do not use periods after such abbreviations as "mm, kg, DOE, NRC, etc."

Taxonomic keys should be in aligned-couplet form in zoology and paleontology, and in multilevel indent form in botany. Synonomy in botany, zoology, and paleontology should be in the short form - taxon, author, year: page - with full citation in the references.

An abstract of not more than 200 words should precede the body of the text. This should be followed by an introduction, methods, results or observations, discussion, and references. In some cases a combination of these sections may be more effective.

References should be checked with the original article and referred to in the text by author and date, in parentheses. References should be listed alphabetically at the end of the manuscript. Reference to papers in periodicals must include author, date, title, journal; volume number, and inclusive pagination. Serials are abbreviated in the form given in **Bibliographic Guide for Editors and Authors** (the American Chemical Society, 1974). For serials not found therein, the abbreviated name in the **World List of Scientific Periodicals** (Butterworths, 1963) is used. The following are examples of style for references from journals, books, and symposium volumes:

Author, A.N. and Other, T.H.E. 1978. Title of the article. *Name of Journal,* (Volume) 99: 1-10. (Omit word volume)
Author, A.N. and Coauthor, A. 1978. *Full Title of Book.* Publisher, City.
Author, A. 1978. Title of Article. In *Title of Book or Symposium Volume.* (ed. J. Smith and B. Jones). Publisher, City, pp. 256-301.

Tables should be numbered with roman numerals, having a brief title, and referred to in the text. Vertical rules should not be used. Talbes must be typed separately from the text on individual pages.

Originals of illustrations should not be more than three times the size of the final reproduction, 11 by 18 cm. Figures, including those in plates, are numbered consecutively in arabic numerals, and each referred to in the text. Original drawings, and one set of clean copy, are required and should be made with india ink on white paper. All lines must be sufficiently thick to reproduce well, and letters and characters sufficiently large to be legible and not less than 1 mm high when reduced. Captions for illustrations should be typed separately from the text.

Photographs should be mounted on heavy bristol board, and ready for reproduction. Prints must be of high quality on glossy paper with no space between those mounted in groups. Photographs of poor quality will be rejected and this, in turn, may require extensive revamping of the ms.

Color illustrations will be accepted at the discretion of the Editor. However, the cost of color reproduction is borne by the authors who must submit a statement accepting this responsibility.

Authors are responsible for editing the galley proof. Orders for reprints, in addition to the 15 supplied gratis, must be received when the galley proof is returned.

RECOMMENDATIONS AUX AUTEURS

La Revue *Proceedings of the Nova Scotian Institute of Science* publie les travaux de l'Institut, des articles originaux et des notes avant trait aux sciences naturelles aux Provinces atlantiques, surtout dans les domaines de la biologie et de la géologie. Les manuscrits peuvent être en anglais ou en français, et seront soumis à l'avis d'experts avant d'être acceptés.

Les textes doivent être dactylographiés à interligne double, sur des feuilles de papier blanc 21.5 cm sur 28 cm (8.5 po sur 11 po), avec marges de 4 cm (1.5 po). Ne souligner que les passages destinés à être imprimés en italique; utiliser les majuscules dans le seul cas où les lettres ou les mots en question doivent paraître en majuscules à l'impression. La mise en page et la typographie suivront le modèle du présent ouvrage. Le texte original doit être accompagné d'une copie. Chaque page doit être numéroté, la première page ne portant que le titre, le nom des auteurs, la mention de l'université ou autre établissement auquel ils sont affectés, et des notes infrapaginales éventuelles.

L'orthographe doit se conformer au **Larousse encyclopédique.** Les auteurs sont responsables de l'uniformité de l'orthographe dans leurs textes.

Les abréviations, la nomenclature et les symboles des unités de mesure doivent se conformer aux normes internationales. Les unités métriques (SI) et les décimales doivent être utilisées dans la mesure du possible. Pour les dates, adopter l'ordre jour/mois/année. Ne pas faire suivre d'un point les abréviations "mm, kg, ME, CNRC", etc.

Les tableaux taxonomiques doivent se présenter, dans des cas de la zoologie et de la paléontologie, sous forme de descriptions dichotomiques alignées verticalement, et pour la botanique sous forme multilinéaire étagée. La synonymie, en botanique, en zoologie et en paléontologie, doit être représentée succinctement: taxon, auteur, année: page, avec citation au complet aux indications bibliographiques.

Un résumé ne dépassant pas 200 mots doit précéder le corps du texte. Le texte lui-même doit comprendre les sections suivantes: introduction, méthodes, résultats ou observations, discussion, références bibliographiques. Dans certains cas, une systhèse de deux ou de plusieurs de ces sections peut être souhaitable.

Les références bibliographiques doivent être vérifiées auprès des publications d'origine, et doivent être identifiées dans le texte par les mentions auteur et date, entre parenthèses. Les références bibliographiques doivent être arrangées par ordre alphabétique en fin de texte. Les références aux articles parus dans des revues doivent comporter les éléments suivants: nom du journal, numéro du volume, pagination complète. L'abréviation des titres revues doivent se conformer au **Bibliographic Guide for Editors and Authors** (American Chemical Company, 1974). Pour les revues qui n'y figurent pas, consultera la **World List of Scientific Periodicals** (Butterworths, 1963). Nous donnon ci-dessous quelques examples de référence aux revues, livres et recueils:

Auteur, U.N. et Autre, T.E.L. 1978. Titre de l'article. *Nom de la revue,* (volume) 99, 1-10, (Omettre le mot "volume").

Auteur, U.N. et Coauteur, S.O.N. 1978. *Titre du livre au complet.* Editeur, Ville.

Auteur, U.N. 1978. Titre de l'article. In *Titre du livre ou du Recueil.* (réd. A. Lenoir et B. Leblanc). Editeur, Ville, pp. 256 - 301.

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